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BUREAU OF MINES MINERALS YEARBOOK

Clays

UNITED STATES DEPARTMENT OF THE INTERIOR

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This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Clays

By Sarkis G. Ampian[1]

Total quantity of clays sold or used by domestic producers increased 7% in tonnage and 10% in value to a new record high $1.20 billion. This increase in production continues the upward trend in clay output for 5 of the last 6 years. Clays in one or more of six classification categories—ball clay, bentonite, common clay and shale, fire clay, fuller's earth, or kaolin—were produced in 44 States and Puerto Rico. Clay production was not reported in Alaska, Delaware, the District of Columbia, Hawaii, Rhode Island, Vermont, or Wisconsin. The leading producing States, in descending order, were Georgia, Texas, North Carolina, Ohio, Alabama, California, and Wyoming. Unpredictable differences in the costs of fuels such as coal, gas, and oil, were still a major concern to clay producers and manufacturers trying to reduce operating costs. Industrywide efforts to economize and obtain alternative competitive fuels, as well as to modernize, were commonplace during 1987. Environmental restrictions and accompanying costs, combined with rising capital costs at yearend, began to slow production.

Production of common clay and shale increased because of an upturn in construction. This upturn was due to low prevailing interest rates and to an improving business climate for most of the year, both of which increased demand for clay building materials. Construction activity, traditionally slow during the last quarter, was further slowed by increases in the prime lending rate. An exception to the Nation's overall buoyant construction industry was noted in the oil-producing States of the Southwest. There, declining revenues depressed overall residential, business, and Government activity. However, steady oil prices and an increased number of operating oil and gas rigs increased optimism in the area during the last quarter, apparently ending the area's malaise.

Increases in production of specialty clays resulted from an improvement in the overall economy and a strong export demand attributed to the weakening U.S. dollar. The declining steel, oil and gas exploration, and foundry industries, all major consumers of specialty clays, had adjusted to their lowest levels of production and prepared to take advantage of both the strong export demand and improved domestic economy.

Table 1.—Salient U.S. clays and clay products statistics[1]

(Thousand short tons and thousand dollars)

	1983	1984	1985	1986	1987
Domestic clays sold or used by producers:					
Quantity	40,858	43,702	44,974	44,620	47,657
Value	$931,092	$1,032,127	$1,011,377	$1,095,179	$1,202,284
Exports:					
Quantity	2,484	2,699	2,780	2,913	3,332
Value	$254,237	$295,733	$309,871	$351,161	$512,964
Imports for consumption:					
Quantity	21	32	41	38	38
Value	$3,488	$4,868	$5,961	$7,501	$9,392
Clay refractories shipments: Value	$595,299	$782,306	$629,738	$529,268	$617,493
Clay construction products shipments: Value	$1,160,543	$1,342,196	$1,427,851	$1,601,640	$1,782,023

[1]Excludes Puerto Rico.

Kaolin accounted for 18% of clay production but 64% of clay value. Kaolin production of 8.8 million short tons and exports of 2.0 million tons were record highs. Ball clay and fuller's earth production matched past record-high years.

Domestic Data Coverage.—Domestic production data for clays are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 1,131 operations covered by the survey, 1,116 responded, representing 99% of the total clay and shale production sold or used and shown in table 1.

Table 2.—Clays sold or used by producers in the United States in 1987, by State[1]

(Short tons unless otherwise specified)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	2,071,090	126,840	--	40,441	[2]2,238,971	[2]$16,216,547
Arizona	--	28,530	189,621	--	--	--	218,151	1,905,317
Arkansas	--	--	706,185	--	--	202,209	908,394	8,651,462
California	--	116,293	2,092,234	--	--	87,805	2,296,332	33,045,543
Colorado	--	160	289,002	--	--	2,948	292,050	1,763,455
Connecticut	--	--	W	--	--	--	W	W
Florida	--	--	127,518	--	431,147	38,522	597,187	39,496,244
Georgia	--	--	2,439,686	--	591,234	7,423,820	10,454,740	756,093,514
Idaho	--	W	W	--	--	8,944	21,781	229,835
Illinois	--	--	232,949	--	W	--	[3]232,949	[3]977,048
Indiana	--	--	1,036,669	W	--	--	[4]1,036,669	[4]4,055,534
Iowa	--	--	472,788	--	--	--	472,788	1,494,770
Kansas	--	W	603,680	--	--	--	[5]603,680	[5]2,675,572
Kentucky	W	--	833,267	W	--	--	[3 4]1,030,512	[3 4]8,829,874
Louisiana	--	--	356,904	--	--	--	356,904	9,191,774
Maine	--	--	W	--	--	--	W	W
Maryland	--	--	383,054	--	--	--	383,054	1,989,968
Massachusetts	--	--	W	--	--	--	W	W
Michigan	--	--	1,333,498	--	--	--	1,333,498	5,338,433
Minnesota	--	--	W	--	--	W	W	W
Mississippi	W	278,871	559,955	--	W	--	1,123,325	26,932,947
Missouri	--	--	1,139,749	336,088	W	--	[3]1,475,837	[3]10,414,581
Montana	--	--	28,879	W	--	--	[4]28,879	[4]98,270
Nebraska	--	--	223,728	--	--	--	223,728	721,059
Nevada	--	11,799	--	--	W	W	65,424	2,468,190
New Hampshire	--	--	W	--	--	--	W	W
New Jersey	--	--	W	5,985	--	--	[5]5,985	[5]139,768
New Mexico	--	--	50,350	898	--	--	51,248	141,110
New York	--	--	672,635	--	--	--	672,635	3,562,468
North Carolina	500	--	3,173,037	--	--	55,516	3,229,053	15,262,025
North Dakota	--	--	50,101	--	--	--	50,101	99,701
Ohio	--	--	2,895,970	291,300	--	--	3,187,270	12,713,992
Oklahoma	--	--	797,301	--	--	--	797,301	1,782,741
Oregon	--	18,147	249,677	--	--	--	267,824	985,880
Pennsylvania	--	--	1,182,748	23,373	--	W	[6]1,206,121	[6]4,750,713
Puerto Rico	--	--	148,029	--	--	--	148,029	317,751
South Carolina	--	--	1,244,886	--	139,194	809,460	2,193,540	[3]38,243,426
South Dakota	--	--	W	--	--	--	W	W
Tennessee	691,570	--	569,303	--	W	--	[3]1,260,873	[3]25,480,282
Texas	W	27,547	3,283,652	4,225	W	W	3,474,976	25,959,476
Utah	--	29,000	286,154	--	--	--	315,154	1,958,941
Virginia	--	--	1,171,442	--	W	--	[3]1,171,442	[3]6,291,100
Washington	--	--	412,031	3,562	--	--	415,593	2,355,954
West Virginia	--	--	266,037	--	--	--	266,037	564,774
Wyoming	--	2,127,645	W	--	--	--	[3]2,127,645	[3]62,031,122
Undistributed	291,735	168,301	703,316	11,280	895,216	157,545	[7]1,569,629	[7]67,509,912
Total	983,805	2,806,233	32,327,725	803,551	2,056,791	8,827,210	47,805,315	1,202,601,873

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Undistributed."
[1]Includes Puerto Rico.
[2]Excludes bentonite.
[3]Excludes fuller's earth.
[4]Excludes fire clay.
[5]Excludes common clay.
[6]Excludes kaolin.
[7]Incomplete total; difference included with individual State totals.

Table 3.—Number of mines[1] from which producers sold or used clays in the United States in 1987, by State

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total
Alabama	--	1	22	5	--	9	37
Arizona	--	5	5	--	--	--	10
Arkansas	--	--	17	--	--	6	23
California	1	5	68	--	--	5	79
Colorado	--	1	32	8	--	--	41
Connecticut	--	--	2	--	--	--	2
Florida	--	--	3	--	4	1	8
Georgia	--	--	16	--	8	86	110
Idaho	--	1	2	1	--	2	5
Illinois	--	--	10	--	2	--	12
Indiana	--	--	16	--	--	2	18
Iowa	--	--	10	--	--	--	10
Kansas	--	1	18	--	--	--	19
Kentucky	6	--	11	1	--	--	19
Louisiana	--	1	8	--	--	--	9
Maine	--	--	3	--	--	--	3
Maryland	1	--	7	--	--	--	8
Massachusetts	--	--	3	--	--	--	3
Michigan	--	--	5	--	--	--	5
Minnesota	--	--	1	--	--	2	3
Mississippi	1	6	20	--	1	--	28
Missouri	--	--	12	42	2	1	57
Montana	--	9	5	1	--	--	15
Nebraska	--	--	5	--	--	--	5
Nevada	--	6	--	--	--	2	8
New Hampshire	--	--	1	--	--	--	1
New Jersey	--	--	1	1	--	--	2
New Mexico	--	--	4	2	--	--	6
New York	1	--	10	--	--	--	11
North Carolina	--	--	54	--	--	2	56
North Dakota	--	--	3	--	--	--	3
Ohio	--	--	58	15	--	--	73
Oklahoma	--	--	18	--	--	--	18
Oregon	--	12	8	--	--	--	20
Pennsylvania	--	--	36	11	--	1	48
South Carolina	--	--	30	--	3	18	51
South Dakota	--	1	1	--	--	--	2
Tennessee	17	--	7	--	3	--	27
Texas	1	11	64	2	1	1	80
Utah	--	3	18	--	1	--	22
Virginia	--	--	15	--	1	--	16
Washington	--	--	10	3	--	--	13
West Virginia	--	--	3	1	--	--	4
Wyoming	--	137	2	--	--	--	139
Total	28	200	646	93	26	138	1,131

[1]Includes both active and idle operations.

DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY TYPE OF CLAY

KAOLIN

Domestic production of kaolin increased 3% to 8.8 million tons, while its reported value increased more than 11% to $775.3 million. Both the reported output and value, for the second consecutive year, reached record highs. Kaolin, in general, and filler grades, in particular, have enjoyed steady increases in demand for the past 15 years, with output rising from 6.0 million tons in 1973 to this year's record-high tonnage of 8.8 million. The average unit value for all grades of kaolin rose about 8% to $87.83 per ton. Kaolin was produced in 13 States, with Georgia and South Carolina accounting for 93% of total production. Arkansas, California, and North Carolina were the other three major producing States. Both Arkansas and California produce refractory- and chemical-grade kaolins. Kaolin producers reported major domestic end uses for their clay as follows: paper coating, 35%; paper filling, 19%; refractories, 8%; fiberglass and insulation, 6%; face brick, 5%; rubber, 4%; and chemicals, 3%.

Kaolin is a white, claylike material approximating the mineral kaolinite. It has a

specific gravity of 2.6 and a fusion point of 1,785° C. The other kaolin-group minerals, such as halloysite and dickite, are encompassed.

Kaolin production was spurred by the continuing growth of the overall economy, particularly increased paper production. Strong demands for paper-, catalyst-, plastic-, and paint-calcined grades, combined with a strong export demand due to the weakening U.S. dollar, led the way. Capacity increases in both washed and calcined grades of the early 1980's were insufficient, at times, to meet demand. Further capacity expansions were either under way or planned by many producers to meet the anticipated demands of the catalyst, paint, paper, and plastic manufacturers. Kaolin sales for refractories appeared to have rebounded slightly at yearend. Increased demand for high-alumina, kaolin-base refractory bricks and specialties by the cement, foundry, and steel industries was mostly responsible. The refractory industry had fully adjusted to new lower levels of production brought about by changes in steelmaking and refractories technology and imports. Production of the three paper-grade kaolins increased in 1987 nearly 11% from 5.3 to 5.9 million tons. Delaminated, water-washed, and low-temperature calcined production increased 16%, 11%, and 6%, respectively.

All Georgia and South Carolina kaolin filler-extender-pigment producers, both air-floated and water-washed, continued to modernize to reduce operating costs and to produce higher valued products. Emphasis continued to be on energy-related costs and on expanding the production capabilities for calcined pigment lines used chiefly by the growing catalyst, paint, paper, plastics, and rubber industries. In this regard, kaolin expansions in Georgia were announced by Engelhard Corp.'s Specialty Chemicals Div. and Anglo-American Clays Corp. (a subsidiary of English China Clays (ECC) America Inc.). At yearend, Thiele Kaolin Co. Inc., Engelhard, broke ground for an $80 million expansion of its calcined kaolin products manufacturing facilities in McIntyre and Gordon. Expected to be completed in late 1988, the enlargement will provide 300,000 tons per year (tpy) of additional calcined and ancillary support equipment. Anglo-American Clays completed its fourth calciner at its Sandersville complex, which will enable it to increase calcined kaolin output by more than 65%. Thiele Kaolin, also in Sandersville, started a $50 million expansion to begin production of calcined kaolin grades. Plans also called for extra mining and processing capabilities to support the new calcining operation. In noncalcined kaolin developments, a newly installed ozone bleaching facility owned by Nord Kaolin Co., a subsidiary of Nord Resources Corp., became fully operational during the year in Jeffersonville. Ozone bleaching is designed primarily to increase reserves by treating otherwise unusable crude gray kaolin clays. Georgia Kaolin Co., a subsidiary of Combustion Engineering Inc., requested permits to use gas-turbine exhausts from cogeneration projects in its spray-dryers at the American Industrial Clay Co. plant in Deepstep. If the permits are granted and the trials are successful on currently installed sprayer baghouses, it will signal a new approach to reducing a major industrywide operating cost. Katalistiks International, a subsidiary of Union Carbide Corp., acquired land in Savannah to set up a new operation for manufacturing a second-generation line of fluid cracking catalysts (FCC) to complement its existing mix of catalysts, supports, and molecular sieves. In a reorganization, Cyprus Minerals Co. Inc. merged four groups of its industrial minerals division into a single unit. Presently, Cyprus Industrial Minerals has three operating companies, one of which produces a full line of soft and hard kaolins in Sandersville and Aiken, SC, respectively.

In development work, Georgia Kaolin undertook a drilling-feasibility study to determine if the quality and quantity of the reserves warranted a kaolin processing facility in Redwood Falls, MN. Nova Natural Resources Inc., also in Minnesota, canceled its request for a permit to operate a kaolin mine in Honner Township. Nova, although still interested in the kaolin project, planned to work jointly with the Northwestern Portland Cement Co.'s kaolin pit. Northwestern presently uses about 50,000 tpy of kaolin in cement production.

Aided by a weakening U.S. dollar and despite strong foreign competition, exports of kaolin, reported as clays by the U.S. Department of Commerce, increased nearly 28% to 2.03 million tons valued at $340 million. The unit value of the exported clay increased to $168.05, or nearly 25% more than that of 1986, indicating that a higher percentage of premium-quality grades was shipped. Kaolin, including calcined material was exported to 56 countries, 17 less than in 1986. The 17 countries were mostly small

importers. The major recipients, in descending order, were Japan, Canada, Italy, the Netherlands, and Mexico. Exports from Finland and Italy increased more than 300% and 50%, respectively. Imports to Finland in the past have been largely from the United Kingdom. Kaolin producers reported end uses for their exports as follows: paper coating, 71%; paper-filling, 18%; rubber, 5%; paint, 2%; and other, including ceramics, plastics, and refractories, the remainder.

Kaolin imports for consumption increased slightly to 10,524 tons valued at $1.4 million. The unit price of kaolin imported from the United Kingdom, the leading source country, rose more than 14% to $129.22 per ton, reflecting the strong worldwide demand for kaolins. China shipped kaolin to domestic consumers for the first time since these statistics were published. Neither the quality nor the grade of the clay was discernible.

Kaolin prices quoted in trade journals generally advanced during the year. Chemical Marketing Reporter, December 28, 1987, quoted prices as follows:

Water-washed, fully calcined, bags, carload lots, f.o.b. Georgia, per ton	[1]$260.00
Calcined, paper-grade, same basis, per ton	350.00
Paper-grade, uncalcined, bulk, carload lots, f.o.b. Georgia, per ton:	
No. 1 coating	98.00
No. 2 coating	76.00
No. 3 coating	73.00
No. 4 coating	[1]73.00
Filler, general purpose, same basis per ton	[1]59.00
Delaminated, water-washed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton	[1]250.00
Dry-ground, air-floated, soft, same basis, per ton	28.00
National Formulary, powder, colloidal, bacteria controlled, 50-pound bags, 5,000-pound lots, per pound	.25

[1]Average of quoted prices.

Table 4.—Kaolin sold or used by producers in the United States, by State

State	1986		1987	
	Short tons	Value	Short tons	Value
Alabama	80,371	$2,396,169	40,441	$1,617,084
Arkansas	190,785	7,152,537	202,209	7,011,203
California	95,048	2,371,925	87,905	3,082,079
Colorado	--	--	2,948	149,586
Florida	35,414	2,771,146	38,522	3,089,946
Georgia	6,778,492	635,219,813	7,423,820	713,524,435
Idaho	1,644	W	8,944	W
Missouri	4,676	47,134	--	--
North Carolina	51,000	1,442,490	55,516	1,516,127
South Carolina	1,063,088	35,588,061	809,460	35,516,618
Other[1]	248,964	3,859,945	157,545	9,784,815
Total	8,549,482	695,849,220	8,827,210	775,291,893

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Includes Minnesota, Nevada, Pennsylvania, Texas, and data indicated by symbol W.

Table 5.—Kaolin sold or used by producers in the United States, by kind

Kind	1986		1987	
	Short tons	Value	Short tons	Value
Air-float	1,454,675	$78,092,960	1,571,742	$74,028,189
Calcined[1]	1,185,088	166,701,281	1,204,459	202,977,802
Delaminated	915,641	56,809,167	1,057,857	103,533,884
Unprocessed	1,121,499	14,712,850	713,415	14,695,875
Water-washed	3,873,579	379,532,962	4,279,737	380,056,143
Total	8,549,482	695,849,220	8,827,210	775,291,893

[1]Includes both low-temperature filler and high-temperature refractory grades.

Table 6.—Calcined kaolin sold or used by producers in the United States, by State

State	High-temperature		Low-temperature	
	Short tons	Value	Short tons	Value
1986				
Alabama and Georgia	478,144	$33,273,985	[1]470,149	[2]$119,288,267
Other	[2]184,244	[2]8,485,118	[3]52,551	[3]5,653,921
Total	662,388	41,759,103	522,700	124,942,178
1987				
Alabama and Georgia	468,809	33,765,315	[1]495,749	[1]154,237,336
Other	[2]180,669	[2]8,124,229	[2]59,232	[3]6,850,922
Total	649,478	41,889,544	554,981	161,088,258

[1]Excludes Alabama.
[2]Includes Arkansas, California (1987), Colorado (1987), Idaho, Missouri (1986).
[3]Includes Pennsylvania and Texas.

Table 7.—Georgia kaolin sold or used by producers, by kind

Kind	1986		1987	
	Short tons	Value	Short tons	Value
Air-float	913,849	$35,111,526	976,909	$38,330,548
Calcined[1]	915,581	159,331,295	924,117	186,385,567
Delaminated	915,641	56,809,167	1,057,857	103,533,884
Unprocessed	210,336	7,297,076	235,591	8,176,477
Water-washed	2,823,085	376,670,749	4,229,346	377,097,959
Total	6,778,492	635,219,813	7,423,820	713,524,435

[1]Includes both low-temperature filler and high-temperature refractory grades.

Table 8.—Georgia kaolin sold or used by producers, by use

(Short tons)

Use	1986				1987			
	Air-float	Unprocessed[1]	Water-washed[2]	Total	Air-float	Unprocessed[1]	Water-washed[2]	Total
Domestic:								
Adhesives	26,438	--	23,978	50,416	26,812	--	19,967	46,779
Aluminum sulfate and other chemicals	--	110,000	--	110,000	--	150,947	--	150,947
Animal feed	30,012	--	--	30,012	33,950	--	--	33,950
Asphalt tile and linoleum	13,512	--	43	13,555	15,558	--	--	15,558
Catalysts (oil refining)	46,016	--	17,153	63,169	20,492	--	45,393	65,885
Face brick	--	--	18,930	18,930	--	18,132	2	18,134
Fiberglass and mineral wool	168,994	--	61,045	230,039	214,444	--	59,253	273,697
Fine china and dinnerware; crockery and earthenware	20,510	1,377	--	21,887	22,732	--	--	22,732
Firebrick, blocks and shapes	62,565	2,723	95	65,383	59,277	8,368	--	67,645
Grogs and calcines, refractory	--	252,709	464	253,173	20,225	420,000	469	440,694
Medical, pharmaceutical, cosmetic	--	--	1,291	1,291	406	--	1,063	1,469
Paint	12,787	--	207,208	219,990	15,672	--	237,768	253,340
Paper coating	--	--	2,313,664	2,313,664	--	--	2,485,279	2,485,279
Paper filling	178,920	--	1,153,431	1,332,351	212,544	--	1,114,071	1,326,615
Plastics	3,600	--	37,297	40,907	425	--	47,742	48,167
Pottery	31,497	689	--	32,186	61,186	--	--	61,186
Refractories[3]	39,091	31,699	8,151	78,941	1,555	28,848	5,014	35,417
Roofing granules	26,249	--	--	26,249	7,313	--	22	7,335
Rubber	31,011	--	20,656	51,667	28,062	--	31,320	59,382
Sanitary ware	128,918	11,705	6,442	147,065	56,511	--	--	56,511
Miscellaneous, air-float:								
Common brick, fertilizers, gypsum products, pesticides and related products, roofing and structural tile, other uses not specified	48,212	--	--	48,212	112,176	--	--	112,176
Miscellaneous, unprocessed:								
Fertilizers, pesticides and related products, other uses not specified	--	54,866	--	54,866	--	37,664	--	37,664
Miscellaneous, water-washed:								
Gypsum products, ink, pesticides and related products, waterproofing and sealing, fertilizers, other uses not specified	--	--	170,388	170,388	--	--	197,958	197,958
Total	868,332	465,768	4,040,331	5,374,431	909,240	663,959	4,245,321	5,818,520

See footnotes at end of table.

Table 8.—Georgia kaolin sold or used by producers, by use —Continued

(Short tons)

Use	1986				1987			
	Air-float	Unprocessed[1]	Water-washed[2]	Total	Air-float	Unprocessed[1]	Water-washed[2]	Total
Exports:								
Paint	124	--	112,446	112,570	127	--	31,985	32,112
Paper coating	27,286	--	776,962	804,248	28,492	--	1,154,774	1,183,266
Paper filling	5,965	--	222,479	227,544	22,700	--	284,347	306,737
Plastics	40	--	--	40	41	--	--	41
Refractories	--	190,000	--	190,000	--	--	--	--
Rubber	--	--	--	--	511	--	23,663	24,174
Undistributed	12,902	--	56,657	69,559	16,108	--	42,862	58,970
Total	45,517	190,000	1,168,544	1,404,061	67,969	--	1,537,631	1,605,300
Grand total	913,849	655,766	5,208,875	6,778,492	976,909	663,959	5,782,952	7,423,820

[1]Includes high-temperature calcined.
[2]Includes low-temperature calcined and delaminated.
[3]Includes electrical porcelain; floor and wall tile (ceramic); flue linings; high-alumina brick and specialties; glazes, glass, enamels; kiln furniture; and refractory mortar and cement.

Table 9.—South Carolina kaolin sold or used by producers, by kind

Kind	1986		1987	
	Short tons	Value	Short tons	Value
Air-float	506,706	$31,298,499	537,116	$32,017,582
Unprocessed	556,363	4,289,562	272,344	3,499,036
Total	1,063,068	35,588,061	809,460	35,516,618

Table 10.—South Carolina kaolin sold or used by producers, by kind and use

(Short tons)

Kind and use	1986	1987
Air-float:		
Adhesives	17,493	18,208
Animal feed and pet waste absorbent	3,608	3,459
Ceramics[1]	3,637	2,896
Fertilizers and pesticides and related products	6,732	29,308
Fiberglass	99,393	143,496
Paint	580	232
Paper coating and filling	8,644	10,547
Plastics	9,591	9,142
Rubber	235,142	194,283
Refractories[2]	5,693	6,073
Other uses[3]	82,743	62,970
Exports[4]	33,471	36,400
Total	506,706	537,116
Unprocessed: Pave brick and other uses	556,363	272,344
Grand total	1,063,068	809,460

[1]Includes floor and wall tile, pottery, and roofing granules.
[2]Includes refractory calcines and grogs; refractory mortar and cement; high-alumina refractories; and firebrick, blocks and shapes.
[3]Includes animal oil; catalysts (oil refining); chemical manufacturing; ink, medical; sewer pipe; and unknown uses.
[4]Includes ceramics, adhesives, paper filling, pesticides and related products, and rubber.

Table 11.—Kaolin sold or used by producers in the United States, by use

(Short tons)

Use	1986				1987			
	Air-float	Unprocessed[1]	Water-washed[2]	Total	Air-float	Unprocessed[1]	Water-washed[2]	Total
Domestic:								
Adhesives	43,921	--	25,978	69,899	45,039	--	22,967	67,987
Aluminum sulfate and other chemicals	--	155,352	--	155,352	--	210,609	--	210,609
Animal feed	33,615	--	3,259	36,874	37,409	--	4,060	41,469
Brick, common and face	6,655	645,269	236	652,180	--	253,239	2	253,241
Catalysts (oil and gas refining)	107,529	--	17,152	124,681	64,261	--	47,911	112,172
Cement, portland	--	304,339	--	304,339	--	81,288	--	81,288
China and dinnerware	20,209	1,377	2,600	24,586	21,827	--	--	21,827
Crockery and other earthenware	W	W	--	W	9,164	--	--	9,164
Electrical porcelain	16,773	--	4,043	20,816	6,460	--	2,393	8,853
Fertilizers[3]	--	--	4,846	4,846	23	--	2,863	2,886
Fiberglass, mineral wool and other insulation	288,387	--	98,990	387,377	358,276	--	100,253	458,529
Firebrick, blocks and shapes	65,091	2,723	95	68,949	84,743	33,846	--	118,589
Floor and wall tile; ceramic glazes, glass, enamels	20,331	5,194	5,719	31,244	12,597	2,723	3,646	18,966
Flue linings, high-alumina brick and specialties	661	97,903	400	98,964	694	68,800	--	69,494
Foundry sand	412	--	--	412	--	--	--	--
Grogs and calcines, refractory	2,794	388,562	464	391,820	22,786	574,956	469	598,211
Gypsum products and wallboard	14,982	3,257	695	19,046	7,746	2,026	4,060	13,772
Ink	--	--	W	W	85	--	2,243	2,328
Kiln furniture, refractory mortar and cement	20,903	36,936	1,389	58,228	2,619	--	1,368	3,987
Linoleum and asphalt tile	13,512	--	4,043	17,555	16,133	--	5,089	21,222
Medical, pharmaceutical, cosmetic	1,629	--	1,291	2,920	2,178	--	1,063	3,241
Paint	13,567	2,760	233,373	250,529	15,904	3,573	287,768	287,245
Paper coating	--	--	2,315,664	2,315,664	--	--	2,487,279	2,487,279
Paper filling	197,564	--	1,153,431	1,340,995	231,091	--	1,114,071	1,345,162
Pesticides and related products	7,004	11,500	2,255	20,778	20,622	17,882	2,300	40,804
Plastics	13,181	--	37,397	50,578	9,567	--	47,742	57,309
Pottery	35,041	689	465	36,195	65,238	--	--	65,238
Roofing granules	26,969	--	1,099	27,968	7,313	--	22	7,335
Roofing and structural tile	349	--	--	348	392	--	--	392
Rubber	286,153	--	21,794	297,947	222,345	--	32,320	254,665
Sanitary ware	13,689	11,795	6,691	146,995	58,437	--	1,000	59,437
Waterproofing and sealing	--	--	W	W	--	4,950	3,724	8,674
Miscellaneous	53,017	12,481	191,833	257,331	120,275	7,334	195,971	323,580
Total	1,371,576	1,570,105	4,135,535	7,077,216	1,443,205	1,361,226	4,350,464	7,154,895

Exports:								
Ceramics	13,337	--	5,804	19,141	9,760	--	--	9,760
Foundry sand, grogs and calcines; other refractories	1,700	212,000	--	213,700	1,849	--	--	1,849
Paint	124	--	118,087	118,211	127	--	35,985	36,112
Paper coating	27,386	--	776,962	804,348	28,492	--	1,154,774	1,183,266
Paper filling	5,120	--	222,479	227,599	22,441	--	284,347	306,788
Plastics	40	--	--	40	41	--	--	41
Rubber	31,403	--	19,983	51,386	55,359	--	23,663	79,022
Miscellaneous	3,989	1,782	32,190	37,961	10,468	1,667	43,342	55,477
Total	83,099	213,782	1,175,385	1,472,266	128,537	1,667	1,542,111	1,672,315
Grand total	1,454,675	1,783,897	5,310,920	8,549,482	1,571,742	1,362,893	5,892,575	8,827,210

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Includes high-temperature calcined.
[2]Includes low-temperature calcined and delaminated.
[3]Includes soil conditioners and mulches.

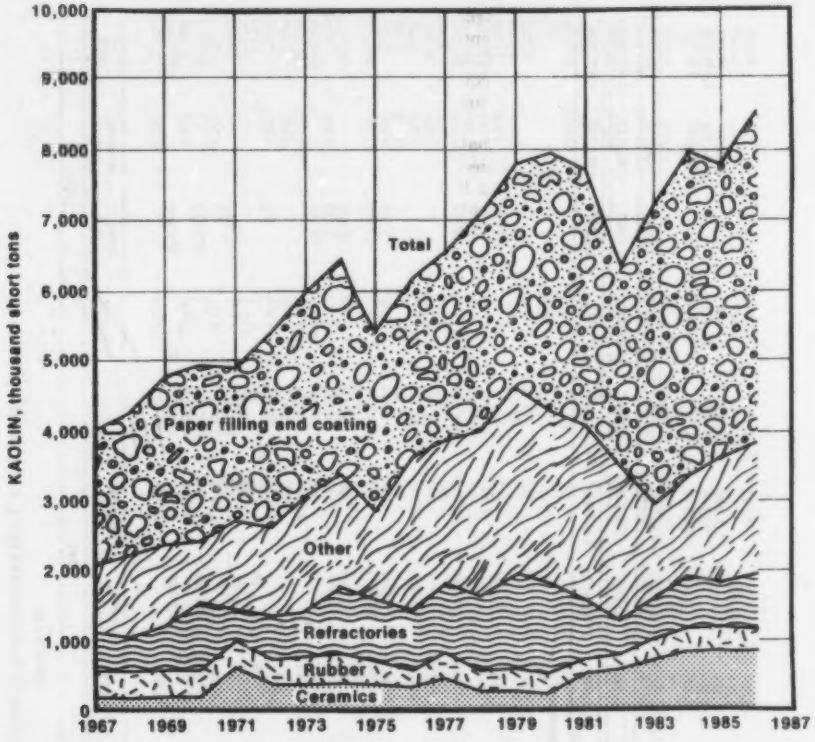

Figure 1.—Kaolin sold or used by domestic producers for specified uses.

BALL CLAY

Production of domestic ball clay increased nearly 11% to approximately 984,000 tons valued at about $36 million. The 1987 production figure is only 3,000 tons under the record-high output of 987,000 tons reported in 1979. Tennessee provided about 70% of the Nation's output, followed, in descending order of production, by Kentucky, Mississippi, Texas, and North Carolina. Production increased in all the major producing States. The growth of the water-slurried Tennessee ball clay demand, combined with the number of producers, now permits publication of selected production statistics. The principal ball clay markets were ceramics, mostly dinnerware, pottery, sanitary ware, and wall tile. Domestic producers continued to enjoy a strong export market usually about 20% of total production, spurred by a weakening U.S. dollar. Continued recovery of the domestic industry, encouraged by competitive interest rates, mortgages, and the improved overall economy during the first three-quarters of the year, increased the demand for ball clays.

Ball clay is a plastic, white-firing clay used principally for bonding in ceramic ware. The clay is of sedimentary origin and consists mainly of the clay mineral kaolinite and sericite mica.

Increased production capacities, modernizations, and/or new plant construction continued cautiously during the year. Ball clay producers either were slowly increasing their capabilities to produce, blend, store, and ship (mostly by slurry-tank rail car) water-slurried clay for ceramic markets or were switching to this capability. In this context, Kentucky-Tennessee Clay Co., Mayfield, KY, created a new slurry by blending and combining the properties of Kentucky clays with those of the existing Tennessee clay slurries. These clays were specifically designed to meet the demands of increasing automation in the ceramic tile industry. H. C. Spinks Clay Co. Inc., Gleason, TN, announced a one-third expansion of storage facilities for its ball clay slurry plant in Gleason to meet increasing demand. In addition, Spinks introduced a

statistical process control (SPC) procedure designed to enhance the consistency and quality of its products. The SPC system involves the use of an extensive computer network to monitor key processes and mineral quality parameters.

The average unit value for ball clay reported by domestic producers decreased 7% to $36.09. Chemical Marketing Reporter, December 28, 1987, listed ball clay prices, unchanged from those of 1986, as follows:

Domestic, air-floated, bags, carload lots, Tennessee, per ton	$49.00
Domestic, crushed, moisture-repellent, bulk carload lots, Tennessee, per ton	24.00

Ball clay exports increased more than 11% to 179,000 tons valued at $6.3 million. Unit value decreased nearly 8% to $35.05 from $38.18 per ton, reflecting a larger percentage of lower valued clays. Shipments were made to 27 countries, 1 more than in 1986. The major recipients, in descending order, were Mexico, Canada, and the Philippines. The expanding Mexican ceramic markets continued to be supplied by domestic clay because of international financial difficulties. Mexican ceramic exports, predominantly to the United States, are fabricated largely with U.S. and domestic clays.

Ball clay imports for consumption, beneficiated and not beneficiated, almost entirely from the United Kingdom, decreased about 41% to 1,759 tons valued at $239,000. The unit value of these clays increased more than 30% to $135.87 per ton, indicating an increasing percentage of the higher valued beneficiated varieties than in previous years.

Table 12.—Ball clay sold or used by producers in the United States, by State

State	Air-float		Water-slurried		Unprocessed		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1986								
Tennessee	[1]426,150	[1]$18,896,722	W	W	189,499	$5,025,280	615,649	$23,922,003
Other	[2]266,380	[2]10,521,659	W	W	[3]5,143	[3]144,271	271,523	10,665,930
Total	692,530	29,418,382	W	W	194,642	5,169,551	887,172	34,587,933
1987								
Tennessee	374,405	15,236,434	108,473	$3,749,623	208,692	5,047,865	691,570	24,027,922
Other[4]	229,632	9,528,799	W	W	W	W	[5]292,235	[5]11,474,807
Total	604,037	24,759,233	108,473	3,749,623	208,692	5,047,865	[5]983,805	[5]35,502,729

W Withheld to avoid disclosing company proprietary data.
[1]Includes water-slurried.
[2]Includes Kentucky, Maryland, Mississippi, and Texas.
[3]Includes California, Kentucky, and Mississippi.
[4]Includes Kentucky, Mississippi, North Carolina, and Texas.
[5]Includes data indicated by symbol W.

Table 13.—Ball clay sold or used by producers in the United States, by use

(Short tons)

Use	1986			1987			
	Air-float[1]	Unprocessed	Total	Air-float[1]	Water-slurried	Unprocessed	Total
Ceramics[2]	43,943	--	43,943	38,790	--	--	38,790
Fillers, extenders, binders[3]	68,817	5,767	74,584	125,070	--	3,924	128,994
Floor and wall tile	98,605	29,700	128,305	77,950	10,590	55,893	144,433
Pottery[4]	17,508	65,841	244,349	148,354	234	76,612	225,200
Refractories[5]	21,340	13,703	35,043	40,493	--	18,350	58,843
Sanitary ware	94,933	54,543	149,476	16,082	95,451	66,918	178,451
Miscellaneous	85,856	11,680	97,536	26,021	--	41,159	67,180
Exports	100,528	13,408	113,936	131,277	2,432	8,205	141,914
Total	692,530	194,642	887,172	604,037	108,707	271,061	983,805

[1]Includes water-slurried.
[2]Includes catalyst (oil refining); fiberglass; glazes, glass, and enamels.
[3]Includes adhesives (1986); animal feed; asphalt emulsions (1987); asphalt tile; paper coating and filling (1986); pesticides and related products; rubber; wallboard (1987); and other uses not specified.
[4]Includes crockery and other earthenware; and fine china and dinnerware.
[5]Includes electrical porcelain; firebrick, blocks and shapes; grogs and calcines (1986); high alumina brick and specialties; and kiln furniture (1986).

FIRE CLAY

Fire clay sold or used by domestic producers increased about 35% in production and value over that of 1986 (which had the lowest reported figures in more than 10 years) to nearly 804,000 tons and $16.8 million, respectively. This increase marked the first major upturn in production in nearly 5 years and was attributed largely to the upswing in the overall economy, exports, and the recovering smokestack industries, which consumed the bulk of manufactured fire clay refractories and clays. Fire clay production declined from the record high of the early 1970's of approximately 4 million tons, to about 2 million tons in the early 1980's, and eventually to the low 1986 amount. Fire clay is detrital material, either plastic or rocklike, containing low percentages of alkalies, iron oxide, lime, and magnesia to enable the material to withstand temperatures of 1,500° C or higher. It is basically kaolinite but usually contains other materials such as ball clay, bauxite clay, diaspore, and shale. Fire clays commonly occur as underclay below coal seams and are generally used for refractories.

Industrywide expansions and modernizations were slowed during the year while acquisitions and/or mergers were prevalent. Manufacturing plants continued to experience phasedowns by either operating intermittently or being put on minimal production schedules. The clay refractory industry had been in a period of low production because of decreased demand brought about by both technological changes and lower consumption levels by its major users, those being steel, nonferrous metals, ceramics, glass, and minerals processing. The technological changes in steelmaking, away from integrated pig iron systems and toward electric furnaces and/or minimills, further compounded the problem by employing shapes and specialty refractories requiring less fire clay. This industry retrenchment prompted USG Corp., at yearend, to spinoff its wholly owned subsidiary, A. P. Green Refractories Co., to its shareholders. Earlier in the year, USG's attempt to sell A. P. Green to Adience Equities Inc., Pittsburgh, PA, failed because of obstacles in financing. The new company, A. P. Green Refractories Inc., was to be operated separately and was to include transferred sections of USG's lime business. Adience, in another fire clay action, agreed to merge with J. H. France Refractories Co. Inc., Snow Shoe, PA, pending approval of both management boards. J. H. France was to be operated as a subsidiary of Adience.

Fire clay production was from mines in 11 States, 1 less than in 1986. Missouri, Ohio, and Alabama, in descending order of volume, accounted for 94% of the total domestic production. Output generally increased significantly in the major producing States, declined in the smaller producing States, and ceased in Colorado.

Exports of fire clay decreased about 8% to 174,000 tons valued at $12.7 million. The unit value of exported clay decreased about 8% to $72.76, indicating that, despite a decrease in exports, the trend of shipping a higher percentage of premium quality calcined material continued. Fire clay was again exported to 26 countries. The major recipients, in descending order, were Japan, Belgium-Luxembourg, Canada, Australia, and Mexico. No imports for consumption were reported for fire clay.

The unit value of fire clay, reported by producers, ranged from about $5.00 to $35.00 per ton, indicating a higher valued fire clay was being recovered and processed.

Table 14.—Fire clay[1] sold or used by producers in the United States, by State

State	1986		1987	
	Short tons	Value	Short tons	Value
Alabama	110,482	$3,113,913	126,840	$3,574,802
Colorado	6,051	80,395	--	--
Missouri	185,758	3,333,844	336,088	7,666,489
New Jersey	12,524	265,919	5,985	139,768
New Mexico	2,103	13,458	898	5,165
Ohio	173,110	3,720,655	291,300	4,588,541
Pennsylvania	44,670	781,657	23,373	600,202
Texas	19,670	139,400	4,225	55,897
Washington	2,676	27,854	3,562	36,004
Other[2]	34,783	738,474	11,280	118,232
Total	591,827	12,215,569	803,551	16,785,100

[1]Refractory uses only.
[2]Includes Arkansas (1986), Idaho (1986), Indiana (1987), Kentucky, and Montana (1987).

BENTONITE

Bentonite production and value decreased slightly to about 2.8 million tons and $90.8 million, respectively. The production was the lowest reported figure in the last 15 years. During that time, production rose steadily to the 1981 record-high 4.9 million tons followed by a steady decline to the 2.8-million-ton 1987 figure. Wyoming, the largest producing State, increased production by more than 22% largely to take up the shortfall brought about by the idling of the nearby Montana operations. Wyoming and Montana had traditionally been the first-and-second-largest swelling bentonite producing States, respectively. Domestic consumption for two major end uses, drilling mud and foundry sand, increased modestly in response to improvements in the overall domestic economy.

Bentonite was produced in 12 States, 1 less than in 1986. The high-swelling or sodium bentonite continued to be produced chiefly in Wyoming. The low-swelling or calcium bentonite continued to be produced in the other States, mostly east of the Mississippi River. Calcium bentonite production in Mississippi is suitable for the production of both absorbent and acid-activated products.

The major western and southern bentonite producers continued flowsheet and other modernizations to reduce plant operating costs and/or overhead. Most plants continued operating sporadically at new lower production levels until about midyear when demand started to increase across the board. The oil industry, spurred on by the increase in the number of operating domestic rigs and favorable long-term oil and gas prices, combined with improvements in the demand for steel and foundry products, brought about an upturn in bentonite demand. The yearend increase in bentonite demand essentially erased poor industry performance in the first half of the year. The foundry, oil and gas, and steel industries traditionally consume about 90% of the domestic output.

The major and captive producers of bentonite either were continuing efforts to expand their product lines in other marketing areas or were restructuring to minimize detrimental aspects of overcapacity. In this regard, American Colloid Co. (ACC), Arlington Heights, IL, purchased additional mining and processing facilities and mineral reserves in the eastern Wyoming sodium bentonite belt from Federal Ore and Chemical Inc., a wholly owned subsidiary of M/I Drilling Fluids Co., Houston, TX, a 60-40 joint venture between Dresser Industries Inc. and the IMCO Services Div. of the Halliburton Co. The purchase also included Federal's taconite-dedicated milling facility in Burnett, MN. ACC also bought the Colony, WY, bentonite operation and some related assets from Applied Industrial Materials Corp. (AIMCOR). The purchase included a processing plant, inventories of mined bentonite, mineral rights, and the assumption of certain liabilities. The purchase excluded AIMCOR's Mississippi-based calcium bentonite and absorbent assets. ACC acquired the clay desiccant product line from Culligan International Inc. and planned to reopen the Dewey County, OK, calcium bentonite mine. The Oklahoma bentonite was targeted for use in the manufacturing of carbonless paper and as a desiccant after processing in ACC's plants in either Belle Fourche, SD, or Upton, WY. American Bentonite Corp.,a newly formed company in Billings, MT, was seeking permits to mine sodium bentonite in Johnson and Montana Counties, WY.

In a Government action, the Senate approved $200,000 to study design alternatives for the underground disposal of low-level nuclear wastes in conjunction with an impervious bentonite clay buffer and/or liner. Reclamation projects under the Surface Mining Law, funded by a $3.8 million construction program approved by the U.S. Department of the Interior, were to involve 20 abandoned bentonite mines in Campbell Johnson, Natrona, and Sheridan Counties, WY. The Wyoming Department of Environmental Quality, Land Quality Div., requested permission from the Army Corps of Engineers to reclaim bentonite pits in isolated wetlands in Crook and Weston Counties.

In calcium bentonite action, Kaisertech Ltd., bought out its partner in the Harshaw/Filtrol Partnership and agreed to sell Harshaw/Filtrol to Engelhard. Harshaw/Filtrol has both a calcium bentonite derived desiccant and acid-activated product line manufactured in Jackson, MS. from local and Arizona clays.

On December 28, 1987, Chemical Marketing Reporter quoted domestic sodium bentonite, 200 mesh, bags, carload lots, f.o.b. mines, as unchanged at $43.50 per ton. The average unit value reported by domestic producers decreased slightly to $32.36 per ton. Per ton values reported in the various producing States ranged from $16 to more than $86, but the average value reported by the larger producers was near the Wyoming average of about $29.15.

Bentonite exports decreased about 7% to

Table 15.—Bentonite sold or used by producers in the United States, by State

State	Nonswelling		Swelling		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1986						
Alabama and Mississippi	454,433	$15,822,614	--	--	454,433	$15,822,614
Arizona	16,166	394,248	25	$788	16,191	395,036
California	104,531	6,841,032	20,686	1,681,950	125,217	8,522,982
Colorado	462	5,544	38	456	500	6,000
Kansas	--	--	24,090	897,990	24,090	897,990
Montana	--	--	182,607	5,779,980	182,607	5,779,980
Nevada	--	--	10,313	583,519	10,313	583,519
Texas	11,969	547,908	20,855	426,913	32,824	974,821
Utah	--	--	7,680	296,294	7,680	296,294
Wyoming	--	--	1,738,412	51,506,278	1,738,412	51,506,278
Other	--	--	[1]220,776	[1]6,584,910	220,776	6,584,910
Total	587,561	23,611,346	2,225,482	67,759,078	2,813,043	91,370,424
1987						
Alabama and Mississippi	423,335	15,609,936	--	--	423,335	15,609,936
Arizona	28,507	904,272	23	805	28,530	905,077
California	95,737	6,867,803	20,556	1,762,662	116,293	8,630,465
Colorado	100	1,600	--	--	100	1,600
Nevada	2,913	310,580	8,786	499,914	11,699	810,494
Oregon	--	--	18,147	639,515	18,147	639,515
Texas	12,343	523,267	15,204	212,324	27,547	735,591
Utah	2,000	20,000	27,000	612,960	29,000	632,960
Wyoming	--	--	2,127,645	62,031,122	2,127,645	62,031,122
Other	--	--	[1]23,837	[1]816,740	23,837	816,740
Total	565,035	24,237,458	2,241,198	66,576,042	2,806,233	90,813,500

[1]Includes Idaho, Kansas (1987), and South Dakota (1986).

Table 16.—Bentonite sold or used by producers in the United States, by use

(Short tons)

Use	1986			1987		
	Non-swelling	Swelling	Total	Non-swelling	Swelling	Total
Domestic:						
Absorbents	75,701	--	75,701	134,371	188	134,559
Adhesives	--	11,302	11,302	7,578	7,582	15,160
Animal feed	43,262	69,164	112,426	12,594	99,162	111,756
Catalysts (oil refining)	5,232	147	5,379	16,901	--	16,901
Drilling mud	5,193	1,031,555	1,036,748	4,509	946,083	950,592
Filtering, clarifying, decolorizing:						
Animal oils, mineral oils and greases, vegetable oils	152,749	2,110	154,859	73,944	2,277	76,221
Desiccants	12,930	--	12,930	16,343	--	16,343
Foundry sand	215,004	401,784	616,788	231,771	418,984	650,755
Medical, pharmaceutical, cosmetic	--	7,321	7,321	--	7,108	7,108
Paint	--	8,446	8,446	--	7,897	7,897
Pelletizing (iron ore)	--	262,419	262,419	--	337,837	337,837
Pesticides and related products	1,163	4,214	5,377	10,403	3,277	13,680
Water treatment and filtering	4,424	935	5,359	4,638	972	5,610
Waterproofing and sealing	4,901	53,062	57,963	1,648	87,991	89,639
Miscellaneous[1]	[r]72,141	[r]57,403	[r]129,544	11,267	43,547	54,814
Total	525,556	1,909,862	2,435,418	525,967	1,962,905	2,488,872
Exports:						
Drilling mud	--	183,934	183,934	1,316	99,646	100,962
Foundry sand	52,760	104,972	157,732	9,054	169,149	178,203
Other[2]	9,245	26,714	35,959	28,698	9,498	38,196
Total	62,005	315,620	377,625	39,068	278,293	317,361
Grand total	587,561	2,225,482	2,813,043	565,035	2,241,198	2,806,233

[r]Revised.

[1]Includes data for asphalt emulsions; asphalt tile; cement, portland; floor and wall tile, ceramic; chemical manufacturing (1986); face brick; fertilizers; firebrick, blocks and shapes; gypsum products; ink; kiln furniture; mineral wool and insulation; oil well sealing (1987); paper coating and filling; plastics; pottery (1987); roofing tile; rubber; and uses not specified.

[2]Includes absorbents (1987); animal feed; asphalt emulsions; cement (1987); filtering, clarifying, decolorizing (1987); paint; plastics; waterproofing and sealing; and uses not specified.

539,000 tons valued at $40.6 million. The unit value of exported bentonite decreased 2% to $75.32 per ton; this was attributed to higher percentages of the lower cost iron ore pelletizing grades, mainly to Canada, over the costlier drilling mud and foundry grades shipped. Domestic bentonite producers, although benefiting from a softening U.S. dollar, continued to face increased competition in foreign markets, particularly the Canadian iron ore markets where Mediterranean bentonites continued to make inroads into an area traditionally served by domestic producers.

Bentonite was exported to 58 countries, 8 less than in 1986. The major recipients were Canada, Japan, Taiwan, Singapore, and the Republic of South Africa. Domestic bentonite producers reported their exports were foundry sand, 56%; drilling mud, 32%; and other, 12%.

Bentonite imports for consumption consisted mostly of both untreated clay and chemically or artificially activated materials. The total bentonite imports increased 18% to nearly 19,000 tons. The chemically activated category, which slowly increased in quantity for most of the past several years, increased 12% to nearly 15,000 tons valued $5.4 million. Imports from the Federal Republic of Germany and Mexico increased nearly 100% and 9%, respectively. Mexican imports usually make up more than 75% of total activated clay imports. The chemically activated bentonite was imported, as last year, from 11 countries, with Mexico supplying 87%; the Republic of South Africa and the Federal Republic of Germany, 11%; and the remaining countries, 2%.

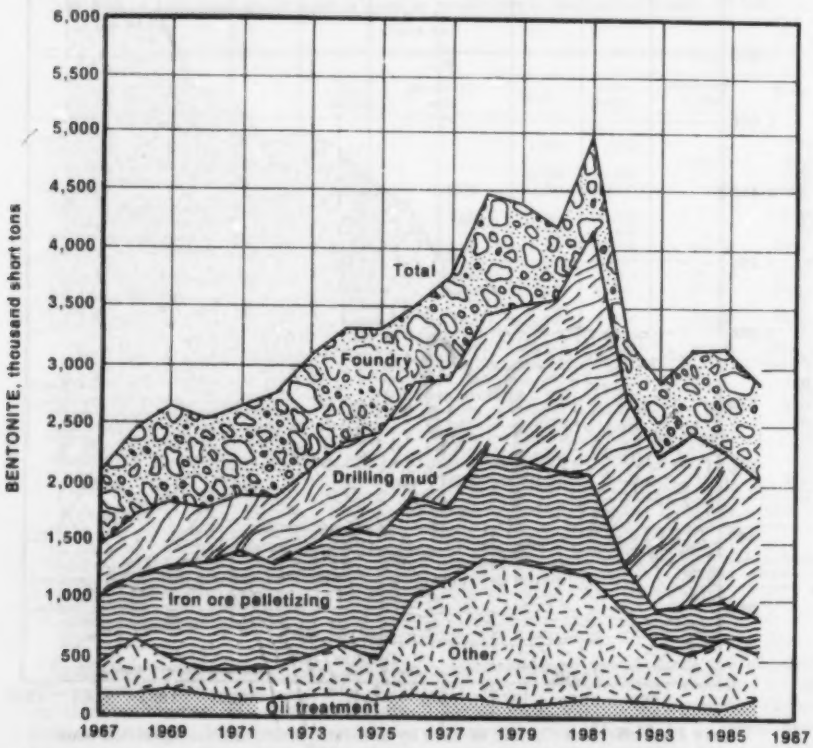

Figure 2.—Bentonite sold or used by domestic producers for specified uses.

FULLER'S EARTH

Production of fuller's earth increased 8% to nearly 2.1 million tons valued at $137 million, essentially equaling the record high of 1985. This increase in production, which followed the first reported decline in 1984 and again in 1986, continued the upward trend in production that the industry has enjoyed for more than 10 years. A general increase in absorbent-grade clay output was sufficient to offset a 7% decline in Florida attapulgite clay production. The average unit value increased slightly to $66.72 per ton, indicating a larger percentage of higher valued gelling grades in the total. Production was reported in 10 States. The two top producing States, Florida and Georgia, accounted for about one-half of domestic production. All States, except Florida and Mississippi, showed gains in production. Increases in consumption occurred across the entire product line of adsorbents, with pet waste absorbents leading the way.

Fuller's earth is a nonplastic clay or claylike material, usually high in magnesia, which has adequate absorbing, decolorizing, and purifying properties. Sepiolite-type clays are also included for statistical convenience.

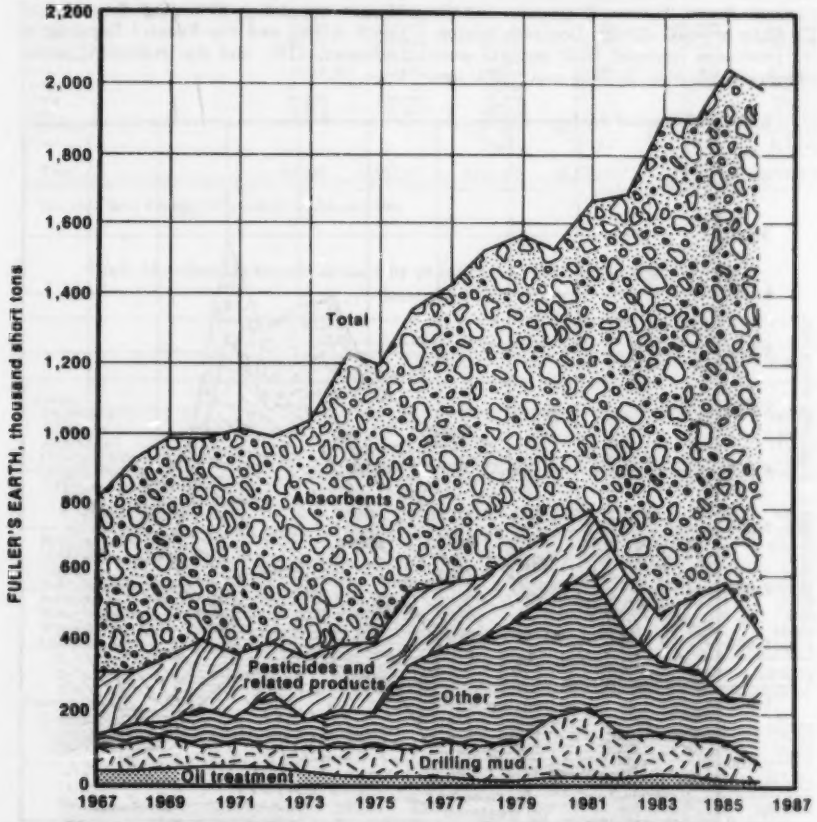

Figure 3.—Fuller's earth sold or used by domestic producers for specified uses

Table 17.—Fuller's earth sold or used by producers in the United States, by State

State	Attapulgite		Montmorillonite		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1986						
Florida	463,246	$38,793,558	--	--	463,246	$38,793,558
Georgia	317,972	15,656,794	213,876	$10,665,217	531,848	26,322,011
Other	[1]139,554	[1]8,172,908	[r 2]775,330	[r 2]52,187,912	[r]914,884	[r]60,360,820
Total	920,772	62,623,260	989,206	62,853,129	1,909,978	125,476,389
1987						
Florida	431,147	35,164,273	--	--	431,147	35,164,273
Georgia	372,411	22,770,583	218,823	12,442,578	591,234	35,213,111
Mississippi, South Carolina, Tennessee, Virginia	--	--	577,558	31,155,549	577,558	31,155
Illinois, Missouri, Nevada, Texas	16,125	1,199,378	440,727	34,499,946	456,852	35,699,324
Total	819,683	59,134,284	1,237,108	78,098,073	2,056,791	137,232,357

[r]Revised.
[1]Includes Illinois, Nevada, and Texas.
[2]Includes Illinois, Mississippi, Missouri, South Carolina, Tennessee, and Virginia.

Table 18.—Fuller's earth sold or used by producers in the United States, by use

(Short tons)

Use	1986			1987		
	Attapulgite	Montmorillonite	Total	Attapulgite	Montmorillonite	Total
Domestic:						
Adhesives	6,874	--	6,874	2,723	--	2,723
Cement, portland and other	--	--	--	--	36,618	36,618
Drilling mud	34,720	--	34,720	31,949	--	31,949
Fertilizers	36,247	7,379	43,626	35,540	6,493	42,033
Filtering, clarifying, decolorizing mineral oils and greases	13,579	--	13,579	13,795	--	13,795
Medical, pharmaceutical, cosmetic	379	--	379	959	--	959
Oil and grease absorbents	264,673	200,694	465,367	163,796	194,738	358,534
Paint	19,885	--	19,885	20,303	--	20,303
Pesticides and related products	71,314	92,675	163,989	17,009	104,208	175,217
Pet waste absorbents	348,710	610,457	959,167	308,320	738,114	1,046,434
Other[1]	13,132	--	13,132	--	--	--
Miscellaneous[2]	47,387	61,462	108,849	90,767	139,194	229,961
Total	856,900	972,667	1,829,567	739,161	1,219,365	1,958,526
Exports:						
Drilling mud	106	--	106	122	--	122
Oil and grease absorbents	23,917	3,031	26,948	43,309	5,908	49,217
Pesticides and related products	4,937	2,589	7,526	5,463	2,270	7,733
Pet waste absorbents	29,506	9,571	39,076	22,461	9,565	32,026
Miscellaneous[3]	5,407	1,348	6,755	9,167	--	9,167
Total	63,872	16,539	80,411	80,522	17,743	98,265
Grand total	920,772	989,206	1,909,978	819,683	1,237,108	2,056,791

[1]Includes roofing tile (1986); roofing granules (1986); tamping dummies (1986); and vegetable oils (1986).
[2]Includes animal feed (1987); animal oils (1987); gypsum products; miscellaneous absorbents; miscellaneous fillers, extenders, and binders; miscellaneous filtering, clarifying, and decolorizing (1987); mortar and cement refractories; plastics; roofing tiles (1987); vegetable oils (1987); wallboard (1987); water treatment and filtering (1987); waterproofing and sealing (1987); and other uses not specified.
[3]Includes paint and uses not specified.

Production from the region that includes Attapulgus, Decatur County, GA, and Quincy, Gadsden County, FL, is composed predominantly of the lath-shaped amphibole-like clay mineral attapulgite. Most of the fuller's earth produced in other areas of the United States contains varieties of montmorillonite and/or other clays.

Throughout the industry, enlargements, modernizations, acquisitions, and/or mergers that had been either canceled or deferred until overall economic conditions improved were starting to be acted upon again cautiously. Generally the absorbent-producing companies enjoyed a good year while the gell-grade producers experienced a mixed year.

Attapulgite, a fuller's earth-type clay,

finds wide application in both absorbent and gelling and/or thickening areas. The thixotropic properties of attapulgite clays provide the important thickening and viscosity controls necessary for suspending solids. Mineral thickeners are used in such diverse markets as paint, joint compound cement, and saltwater drilling muds.

Prices for attapulgite reported by producers ranged from about $80 to $120 per ton; montmorillonite prices ranged from about $20 to $90.

Exports of fuller's earth went to 28 countries, 4 less than in 1986, but the quantity decreased nearly 12% to 107,000 tons valued at $8.7 million. The unit value of exported fuller's earth increased slightly over that of 1986 to $81.03, which was attributed to a larger percentage of the high-cost gelling and drilling-mud grades exported in 1987 compared with the percentage of absorbent grades shipped. The major recipients were Canada and the Netherlands. A minor amount of beneficiated and unbeneficiated fuller's earth was imported, mostly from France.

COMMON CLAY AND SHALE

Domestic sales or use of common clay and shale increased about 8% in both tonnage and value to 32.3 million tons and $147 million. Output of the 10 major producing States rose in Alabama, North Carolina, Ohio, South Carolina, Texas, and Virginia, and declined in California, Georgia, Michigan, and Pennsylvania. Common clay and shale represented about 70% of the quantity but only 12% of the value of total domestic clay production. Domestic clay and shale are generally mined and used captively to fabricate or manufacture products. Less than 10% of the total output is usually sold. The average unit value for all common clay and shale produced in the United States and Puerto Rico increased slightly to $4.56 per ton. The unit value ranged from $13 to nearly $30 per ton.

Common clay is a clay or claylike material that is sufficiently plastic to permit ready molding and that vitrifies below 1,100° C. Shale is a sedimentary rock composed chiefly of clay minerals that has been both laminated and indurated while buried under other sediments. Clay and shale are used in the manufacture of structural clay products such as brick, drain tile, portland cement clinker, and expanded lightweight aggregates.

Increased production capacities, new plants, and modernizations, previously deferred, were beginning to be acted on again. Mergers and/or acquisitions of domestic heavy clay producers were quite active. The construction industry, the biggest user of heavy clay products such as brick, lightweight aggregate, portland cement, sewer pipe, and tiles, was moving along at a brisk pace. The large inventories traditionally accumulated during the winter months were worked off by the first quarter, and at midyear, the industry was experiencing heavy production. Output during the last quarter was somewhat tempered by increasing interest rates. A notable exception to these boom times was the declining construction rates in the depressed oil-producing States of the Southwest.

In building brick acquisitions, Steetley PLC, through its subsidiary, Steetley Brick and Tile Ltd., purchased K-F Brick Co. Inc. and Victor Cushwa and Sons Inc., Williamsport, MD. K-F Brick, the leading New England supplier of face bricks, has plants in Connecticut and Massachusetts with a combined capacity of 80 million bricks per year (bpy). Cushwa produces about 40 million bpy of quality face bricks, mostly machine-molded with some hand-thrown brick targeted for the higher priced end of the market. Both K-F Brick and Cushwa, the latter strategically situated in the Baltimore, MD-Washington, DC, area, serve market areas that have favorable long-term growth prospects. Marley PLC, through its U.S. subsidiary, General Shale Products Corp., a major U.S. brick producer, acquired Corbin Brick Co. Inc., Corbin, KY. Corbin has a maximum production capacity of 100 million bpy of high-quality face bricks with the recent addition of its new kiln. General Shale's total capacity in the United States is now reported to be in excess of 800 million bpy. Jannock Ltd. a Toronto, Canada, brick producer, bought Payne Brick Co. of Elgin, TX, for an undisclosed amount. The Payne Brick operation has a capacity of 24 million bpy and clay reserves for at least 50 years. Tarmac-Lonestar Inc., a joint venture between Tarmac America and Lonestar Inc., purchased the assets of Old Virginia Brick Co. Inc., Salem, VA. Old Virginia is currently expanding its molded capacity to more than 40 million bpy. The enlargement includes a newly automated second kiln and other ancillary equipment. Tarmac PLC is a major producer of building raw materials and products in the United Kingdom.

In a nonbrick common clay and shale acquisition, Cement Roadstone Holdings PLC (CRH) based in Dublin, Ireland, bought Big River Industries Inc. of Baton Rouge, LA. Big River is a major U.S. producer of expanded clay and/or shale lightweight aggregate, with manufacturing plants in Ala-

bama, Georgia, and Louisiana. Big River successfully barges expanded aggregates along the Mississippi and its tributaries. CRH already owns concrete block, pipe, and aggregate operations in the United States. In another buyout, Mission Clay Products Corp., a clay and building products manufacturer in Los Angeles, CA, acquired W. S. Dickey Clay Manufacturing Co.'s Pittsburgh, KS, and San Antonio, TX, clay sewer pipe manufacturing plants from Hepworth Ceramic Holdings Ltd. of Sheffield, United Kingdom.

Exceptions to the industrywide slowdown in expansions and modernizations were announced by Acme Brick Co., a subsidiary of Justin Industries Inc., and several other companies. Acme Brick's two new brick plants became operational in Tulsa, OK, and near Houston, TX. Hanley Brick Co., a unit of the Glen-Gery Corp., Reading, PA, began production at its new brickworks in Marion County, OH. The new plant was also producing a line of molded bricks to augment its present extruded products. A second kiln was scheduled to come on-stream by yearend 1988. L. C. Holdings Inc., a Boulder, CO, operation, announced plans to reactivate the former Idealite expanded shale lightweight aggregate plant near Golden, CO. The refurbished plant was to be capable of producing about 500,000 cubic yards of lightweight material for the Denver market area, which includes the newly planned Denver airport. Increases in production capacity were announced by Robinson Brick Co. Inc. during the year. Robinson Brick fired up its idle second kiln and scheduled a second shift to handle the increased production. Watsontown Brick Corp., Watsontown, PA, opened its new grinding plant complete with a single roller crusher, screens, assorted belt conveyors, and a hammermill to feed the pugmill. In new products, Higgins Brick Co. Inc., Redondo Beach, CA, introduced a novel hollow standard-size brick with full strength and load-bearing capabilities. Previously, hollow bricks were available in larger dimensions only.

Table 19.—Common clay and shale sold or used by producers in the United States,[1] by State

State	1986		1987	
	Short tons	Value	Short tons	Value
Alabama	1,886,574	$9,318,166	2,071,690	$11,024,661
Arizona	184,919	971,190	189,621	1,000,240
Arkansas	783,588	1,845,190	706,185	1,640,259
California	2,228,871	22,393,865	2,092,234	21,332,999
Colorado	235,782	1,436,684	289,002	1,612,269
Connecticut and New Jersey	276,680	2,775,207	248,437	2,599,275
Florida	227,243	1,695,847	127,518	1,241,925
Georgia	2,516,322	7,657,913	2,439,686	7,355,968
Illinois	282,993	1,091,609	232,949	977,048
Indiana	743,859	3,043,873	1,036,669	4,055,534
Iowa	486,309	1,420,979	472,788	1,494,770
Kansas	879,358	4,397,191	603,680	2,575,572
Kentucky	661,176	2,305,585	721,111	3,450,418
Louisiana	331,982	7,669,853	356,904	9,191,774
Maine and Massachusetts	185,995	961,199	189,562	942,329
Maryland	361,729	1,757,132	283,054	1,939,968
Michigan	1,402,446	5,684,283	1,333,498	5,338,433
Mississippi	616,672	2,747,815	559,955	2,706,996
Missouri	1,130,333	3,269,320	1,139,749	2,748,092
Montana	39,212	101,724	28,879	98,270
Nebraska	221,153	668,380	223,728	721,059
New Mexico	58,081	156,663	50,350	135,945
New York	618,968	3,074,611	672,635	3,562,468
North Carolina	2,606,679	9,527,534	3,173,037	13,765,148
Ohio	2,659,675	7,794,754	2,895,970	8,125,451
Oklahoma	992,702	2,328,697	797,301	1,782,741
Oregon	203,596	288,920	249,677	346,365
Pennsylvania	1,189,121	4,278,881	1,182,748	4,150,511
Puerto Rico	110,997	222,845	148,029	317,751
South Carolina	923,165	2,392,204	1,244,886	2,726,808
South Dakota and Wyoming	141,941	691,641	194,700	1,756,372
Tennessee	548,641	1,305,695	569,303	1,452,360
Texas	2,423,685	10,609,847	3,283,652	14,032,898
Utah	296,867	1,751,735	286,154	1,325,941
Virginia	855,977	4,699,648	1,171,442	6,291,100
Washington	249,469	1,531,913	412,031	2,319,950
West Virginia	214,980	469,708	266,037	564,574
Other[2]	141,401	419,360	120,718	329,849
Total	29,979,076	135,902,494	32,327,725	146,976,294

[1]Includes Puerto Rico.
[2]Includes Idaho, New Hampshire, and North Dakota.

CONSUMPTION AND USES

The manufacture of heavy clay products including building brick; sewer pipe; and drain, roofing, structural, terra cotta, and other tile; portland cement clinker; and lightweight aggregate accounted for 38%, 18%, and 10%, respectively, of total domestic consumption. In summary, 70% of all clay produced was consumed in the manufacture of these clay- and shale-based construction materials.

Heavy Clay Products.—The value reported by the Bureau of the Census for shipments of heavy clay products increased 11% to about $1.8 billion. The million standard brick count for building or common face brick increased slightly. Shipments of vitrified clay and sewer pipe fittings increased 9%, while clay floor and wall tile increased 4%. Increases in common clay and shale used in building brick manufacturing occurred in most States with total domestic production increasing 6%. Increases were less than 13% with an average State upturn of less than 20%.

Lightweight Aggregates.—Consumption of clay and shale in the manufacture of lightweight aggregate increased about 24% to nearly 4.6 million tons. The upturn in overall construction of commercial buildings and highway resurfacing was largely responsible for the increase in demand. Concrete block, the largest category (61% of total production), rose 15% while the second biggest consuming area, highway surfacing (19% of total production), increased markedly. The third largest segment, structural concrete (18% of production), declined 20% and the other category, the smallest segment consisting essentially of new market areas such as recreational and horticultural uses, also rose 94%.

Refractories.—All types of clay were used in manufacturing refractories. Kaolin, bentonite, and fire clay accounted for 32%, 27%, and 26%, respectively, of total clay used for this purpose. The remainder, ball clay, common clay and shale, and fuller's earth, was used chiefly as bonding agents. Bentonite, both swelling and nonswelling, was used as a bonding agent in proprietary foundry formulations imparting both green- and hot-strength to the sand.

The tonnage of clays used for refractories increased 12% and constituted 5% of total clay produced. The continued use of refractories, mostly calcined kaolin grogs, in monoliths, and the upturn in demand for the more conventional refractory bricks and shapes was largely responsible. The major refractory-consuming industries—cement, foundry, glass, and ferrous and nonferrous metals—continued to undergo major changes in technology and production levels for their products.

Filler.—Bentonite, fuller's earth, and kaolin, are the principal filler clays. Kaolin, either air-floated, water-washed, low-temperature calcined, and/or delaminated, was used in the manufacture of adhesives, paint, paper, plastics, and rubber. Fuller's earth was used primarily in pesticides and fertilizers. Clays are in pesticides and fertilizers as either thickeners, carriers, diluents, or prilling agents. Bentonites were used mainly in animal feeds.

Of the total clay produced, 11% was used in filler applications; of this, kaolin accounted for 88%; fuller's earth, 5%; bentonite, 3%; and ball clay, common clay and shale, and fire clay, the remaining 4%. Kaolin consumed as fillers increased to 4.8 million tons. An approximate 15% increase in paint and a slight increase in paper filling, which together constitute 30% of the total filler and extender category, were largely responsible. The paper-coating grade kaolin, animal feed, and gypsum products and wallboard, together made up a 7% increase. The total quantity of fuller's earth used in pesticides and related products such as fungicides, increased nearly 7% from that of 1986.

Absorbent Uses.—Absorbent uses for clays accounted for nearly 1.7 million tons, or 4% of total clay consumption. Demand for absorbents increased slightly. Fuller's earth was the principal clay used for absorbent purposes, and this application accounted for 69% of the entire output. Demand for clays in pet waste absorbents, representing 61% of absorbent uses, increased 9%. Use in floor absorbents, chiefly to absorb hazardous oily substances, accounted for another 21% of the absorbent demand, which decreased from that of 1986. An increase in the use of pet waste absorbents offset the decline in the industrial sector, which consumes large quantities of floor absorbents.

Table 20.—Clays sold or used by producers in the United States[1] in 1987, by use

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Absorbents:							
Oil and grease	--	W	W	--	358,534	--	358,534
Pet waste	--	W	W	--	1,046,434	--	1,046,434
Other[2]	--	142,396	166,198	--	11,850	--	309,444
Ceramics and glass:							
Catalysts (oil refining)	--	16,901	--	--	--	112,172	129,073
Crockery and other earthenware	--	--	W	7,080	--	9,164	16,244
Electrical porcelain	27,462	--	45	--	--	8,853	36,350
Fine china and dinnerware	13,204	--	--	--	--	21,827	35,031
Glazes, glass, enamels	--	--	--	--	--	638	638
Mineral wool and insulation, fiberglass	W	W	--	--	--	458,529	458,529
Pottery	211,996	10	19,748	4,900	--	65,238	300,992
Roofing granules	--	--	48,530	4,933	--	7,335	59,898
Sanitary ware	178,451	--	--	300	--	59,437	238,188
Other[2]	73,943	2,541	8,731	4,232	--	61,149	145,596
Chemical manufacturing	--	--	--	--	--	212,752	212,752
Civil engineering and sealing	--	99,026	183,115	530	139,364	16,052	438,087
Drilling mud	--	950,592	--	--	31,949	632	983,173
Fillers, extenders, binders:							
Adhesives	--	15,160	--	--	2,723	67,987	85,870
Animal feed	W	111,736	W	--	W	41,409	153,165
Fertilizers	--	W	--	--	42,023	2,896	44,919
Gypsum products and wallboard	W	--	--	--	24,783	12,772	39,555
Ink	--	W	--	--	--	2,328	2,328
Medical, pharmaceutical, cosmetic	--	--	--	--	959	3,241	11,308
Paint	--	7,168	1,750	--	20,303	297,245	317,195
Paper coating	--	7,897	--	--	--	2,487,279	2,487,279
Paper filling	--	W	W	--	--	1,345,162	1,345,162
Pesticides and related products	W	13,680	3,368	--	175,217	40,804	233,069
Plastics	--	W	--	--	W	57,309	57,309
Rubber	W	W	1,411	W	--	254,665	256,076
Other[2]	128,994	19,655	83,882	5,400	16,534	188,302	442,767
Filtering, clarifying, decolorizing:							
Animal oils, mineral oils and greases, vegetable oils	--	76,221	--	--	34,538	606	111,365
Desiccants	--	16,343	--	--	--	--	16,343
Floor and wall tile:							
Ceramic	144,433	--	203,147	805	--	W	348,385
Quarry tile	--	--	154,704	135	--	--	154,839
Other[3]	--	12	196,000	--	--	38,019	234,031

See footnotes at end of table.

Table 20.—Clays sold or used by producers in the United States[1] in 1987, by use —Continued

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Total
Heavy clay products:							
Brick, extruded	24,785	2,950	12,592,804	19,280	--	269,051	12,909,971
Brick, other	--	--	4,088,510	14,574	--	84,210	4,187,294
Cement, portland and other	--	1,171	8,410,247	1,625	36,618	81,288	8,530,949
Drain tile	--	--	34,004	--	--	--	34,004
Flower pots	--	--	39,967	310	--	--	40,277
Flue liners	--	--	36,907	66,179	--	29,600	130,686
Roofing tile	--	186	200	--	191	--	527
Sewer pipe, vitrified	--	--	388,286	--	--	6,835	395,283
Structural tile	--	--	55,005	--	--	992	56,197
Terra cotta	--	--	16	523	--	--	539
Other	--	--	719,491	--	--	19,387	738,879
Lightweight aggregate:							
Concrete block	--	--	2,792,779	--	--	125	2,792,904
Highway surfacing	--	--	802,364	--	--	--	802,364
Structural concrete	--	--	845,557	--	--	--	845,557
Other	--	--	122,297	--	--	--	122,297
Pelletizing iron ore	--	327,827	--	--	--	--	327,827
Refractories:							
Firebrick, blocks and shapes	W	W	92,186	417,324	--	118,569	628,079
Foundry sand	--	650,756	--	42,657	--	--	693,412
Grogs and calcines	--	--	--	139,365	--	596,211	736,586
High alumina brick and specialties	22,219	--	--	43,154	--	40,694	106,067
Kiln furniture	--	526	2,943	--	--	W	2,481
Mortar and cement, refractory	--	--	225,099	--	22	--	225,121
Other[2]	9,162	13,980	--	--	--	92,250	54,772
Other[3]	7,242	1,819	2,080	26,596	15,474	10,241	63,282
Exports	141,914	317,861	11,592	7,426	98,265	1,672,315	2,248,873
Total	983,805	2,806,233	32,327,725	803,551	2,056,791	8,827,210	47,805,315

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Other."

[1]Includes Puerto Rico.

[2]Includes uses indicated by symbol W.

[3]Uses not specified.

Table 21.—Shipments of principal structural clay products in the United States

Product		1983	1984	1985	1986	1987
Unglazed common and fire brick:						
Quantity	million standard brick	5,792	6,510	6,605	7,204	7,313
Value	million	$704	$836	$897	$972	$1,060
Unglazed structural tile						
Quantity	thousand short tons	30	32	55	72	[1]93
Value	million	$5	$7	$12	$28	[1]$50
Vitrified clay and sewer pipe fittings:						
Quantity	thousand short tons	375	397	368	298	325
Value	million	$64	$79	$78	$66	$74
Unglazed, salt-glazed, ceramic-glazed structural facing tile including glazed brick:						
Quantity	million standard brick	W	W	W	W	32
Value	million	W	W	W	W	$11
Clay floor and wall tile including quarry tile:						
Quantity	million square feet	334	340	370	444	462
Value	million	$388	$421	$450	$536	$587
Total value[2]	do.	$1,161	$1,342	$1,428	$1,602	$1,782

W Withheld to avoid disclosing company proprietary data.
[1]Includes first 9 months only.
[2]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census Report Form M22-D(87), Current Industrial Reports—Clay Construction Products.

Table 22.—Common clay and shale used in building brick production in the United States, by State

State	1986		1987[1]	
	Short tons	Value	Short tons	Value
Alabama	865,906	$4,034,526	973,878	$4,392,725
Arizona[2] and New Mexico[2]	137,740	407,962	141,992	483,466
Arkansas	486,068	1,421,375	192,388	447,054
California	485,354	8,095,174	456,618	8,036,489
Colorado	234,462	1,423,154	289,002	1,551,504
Connecticut, New Jersey,[2] New York[2]	422,071	2,921,398	403,161	2,759,099
Georgia	2,003,595	5,597,706	2,104,724	5,919,878
Idaho, Washington, Wyoming[2]	172,540	963,046	318,543	1,274,167
Illinois	118,675	561,858	131,787	614,170
Indiana and Iowa	391,850	1,010,698	432,908	1,364,579
Kansas	220,216	601,563	191,780	554,907
Kentucky[2]	397,918	1,409,109	394,692	2,100,514
Louisiana	98,982	253,463	73,672	176,499
Maine, Massachusetts,[2] New Hampshire[2]	199,995	1,093,499	207,062	1,095,799
Maryland and West Virginia[2]	388,472	1,781,917	422,113	1,976,791
Michigan[2] and Minnesota[2]	148,206	538,794	208,872	586,815
Mississippi	515,854	2,415,116	479,955	2,429,796
Missouri	98,471	423,519	166,822	469,798
Nebraska and North Dakota[2]	217,351	559,753	187,619	493,162
North Carolina	2,290,572	8,671,986	2,806,044	10,844,565
Ohio	1,617,522	4,492,329	1,252,827	3,872,507
Oklahoma	462,895	1,374,819	374,343	973,542
Oregon	19,840	51,446	21,297	58,521
Pennsylvania	885,694	2,621,100	967,313	3,212,185
South Carolina	608,616	1,606,223	962,223	2,310,141
Tennessee[2]	430,668	951,776	442,786	1,053,831
Texas	1,114,128	4,581,541	1,185,246	4,935,894
Utah[2]	126,357	939,910	141,625	723,399
Virginia	729,196	2,188,494	970,018	2,681,587
Total	15,868,124	62,974,259	[4]16,681,314	[4]67,323,384

[1]Includes extruded and other brick.
[2]Extruded brick only (1987).
[3]Other brick only (1987).
[4]Includes 1.5 million tons used in other brick production.

Drilling Mud.—Demand for clays in rotary-drilling muds decreased 8% to about 983,000 tons and accounted for 2% of total clay production. This decrease reflected the downward trend, except for the increase noted in 1984, begun in 1982 when a combination of excess oil production and economic uncertainties resulted in lower oil- and gas-well-drilling activities, which depressed bentonite demand. Oil- and gas-well-drilling activity picked up at yearend because of price stability and a favorable long-term outlook. Swelling-type bentonite remained the principal clay used in drilling mud mixes, although fuller's earth, used mostly in salt water drilling techniques, and nonswelling sodium-activated bentonites, were also used to a limited extent. Bentonite and fuller's earth accounted for nearly 100% of the total amount of clay used in this category. Small amounts of kaolin were used in specialized formulations.

Floor and Wall Tile.—Common clay and shale, ball clay, kaolin, fire clay, and bentonite, in order of volume, were used in manufacturing floor, wall, and quarry tile. This end-use category accounted for 2% of total clay production. The competitive and/or declining interest for most of the year spurred the demand for more attractively appointed tiled homes.

Pelletizing Iron Ore.—Bentonite continued to be used as a binder in forming indurated iron ore pellets. Demand increased nearly 29% to about 338,000 tons. Inroads of inexpensive foreign bentonites into the Great Lakes markets traditionally served by exclusively U.S. bentonite producers, lower production levels, metal imports, and changing technology have all combined to reduce the long-term demand for domestic bentonite in this category.

Ceramics and Glass.—Total demand for clay in the manufacture of pottery, sanitary ware, china and dinnerware, and related products (excluding clay flower pots) accounted for 3% of the total clay output. This demand, principally ball and kaolin clays, increased slightly to 1.42 million tons. The strong upturn in residential housing, large consumers of whiteware and sanitary ware, was partially offset by the soft demand for these products at yearend owing to rising interest rates.

Table 23.—Common clay and shale used in lightweight aggregate production in the United States, by State

State	Short tons					Total value
	Concrete block	Structural concrete	Highway surfacing	Other	Total	
1986						
Alabama and Arkansas	489,707	228,638	12,491	8,487	789,323	$4,455,545
California	52,180	219,322	--	--	271,502	2,331,579
Florida and Indiana	236,923	38,550	--	--	275,473	3,714,804
Kansas, Kentucky, Louisiana	466,170	139,350	12,320	5,400	623,240	13,175,358
Mississippi and Missouri	182,431	7,057	10,082	--	199,570	1,229,367
Montana and New York	181,766	172,550	--	--	354,316	5,602,754
North Carolina	231,300	77,100	--	--	308,400	6,797,136
Ohio, Oklahoma, Pennsylvania	216,643	35,580	2,199	--	254,422	637,623
Texas	181,969	32,301	142,965	48,002	405,237	1,686,181
Utah and Virginia	187,112	51,820	14,809	1,040	254,781	3,025,714
Total	2,426,201	1,002,268	194,866	62,929	3,686,264	42,656,061
1987						
Alabama and Arkansas	743,549	91,433	16,674	25,348	877,004	6,015,176
California	57,000	57,000	--	--	114,000	592,572
Florida and Indiana	202,832	28,750	--	--	231,582	1,506,486
Kansas, Kentucky, Louisiana	380,563	132,349	26,674	4,019	543,605	10,359,005
Mississippi	50,000	10,000	20,000	--	80,000	271,200
Montana and New York	243,610	163,717	--	--	407,327	2,992,566
North Carolina	270,000	90,000	--	--	260,000	2,836,800
Ohio, Oklahoma, Pennsylvania	295,678	14,759	2,016	--	312,453	754,220
Texas	228,194	134,547	771,568	91,880	1,226,189	5,154,821
Utah and Virginia	321,353	79,809	8,625	1,040	410,827	4,071,305
Total	2,792,779	802,364	845,567	122,287	4,562,987	34,562,151

Table 24.—Shipments of refractories in the United States, by product

Product	Unit of quantity	1986		1987	
		Quantity	Value (thousands)	Quantity	Value (thousands)
CLAY REFRACTORIES					
Superduty fire clay brick and shapes	1,000 9-inch equivalent.	21,968	$26,697	27,070	$27,914
Other fire clay including semisilica brick and shapes, glasshouse pots, tank blocks, feeder parts, upper structure parts used only for glass tanks.	do	56,685	40,603	62,006	46,126
High-alumina (50% to 60% Al_2O_3) brick and shapes made of calcined diaspore or bauxite.[1]	do	65,716	118,042	76,004	128,404
Insulating firebrick and shapes	do	--	--	21,158	20,344
Ladle brick	do	30,330	9,985	10,302	3,272
Sleeves, nozzles, runner brick, tuyeres	do	25,279	29,327	9,679	28,315
Hot-top refractories	Short tons	W	W	W	W
Kiln furniture, radiant heater elements, potter's supplies, other miscellaneous-shaped refractory items.	do	27,185	21,965	42,432	33,246
Refractory bonding mortars	do	79,042	37,156	56,619	29,296
Plastic refractories and ramming mixes, containing up to 87.5% Al_2O_3.[2]	do	75,893	36,669	64,051	32,816
Castable refractories	do	207,150	73,075	251,808	110,578
Gunning mixes	do	144,882	37,497	144,940	50,475
Other clay refractory materials sold in lump or ground form.[3 4]	do	502,625	98,252	885,558	106,707
Total clay refractories		XX	529,268	XX	617,493
NONCLAY REFRACTORIES					
Silica brick and shapes	1,000 9-inch equivalent.	4,582	11,825	6,861	19,028
Magnesite and magnesite-chrome brick and shapes.	do	19,467	94,933	21,745	107,987
Chrome and chrome-magnesite brick and shapes.	do	22,914	82,347	27,640	101,124
Shaped refractories containing natural graphite.	Short tons	11,548	32,728	17,251	40,117
Zircon and zirconia brick and shapes; other carbon refractories: Forsterite, pyrophyllite, dolomite, dolomite-magnesite molten-cast,[5] other brick and shapes.	1,000 9-inch equivalent.	1,557	31,669	1,716	21,924
Other mullite, kyanite, sillimanite, or andalusite brick and shapes.	do	2,825	15,980	2,702	19,108
Other extra-high (over 60%) alumina brick and fused bauxite, fused alumina, dense-sintered alumina shapes.[6]	do	4,141	63,508	3,287	58,119
Silicon carbide brick, shapes, kiln furniture	do	979	28,880	1,105	33,936
Refractory bonding mortars	Short tons	21,094	11,539	29,843	16,944
Hydraulic-setting nonclay refractory castables	do	19,023	18,227	28,837	21,999
Plastic refractories and ramming mixes	do	120,306	75,922	136,738	89,385
Gunning mixes	do	364,806	150,950	323,330	111,939
Dead-burned magnesia or magnesite[3 7]	do	250,990	64,347	141,967	34,374
Dead-burned dolomite	do	324,691	46,393	331,982	19,682
Other nonclay refractory material sold in lump or ground form.[3]	do	280,886	74,655	202,486	42,137
Total nonclay refractories		XX	803,903	XX	737,803
Grand total refractories		XX	1,333,171	XX	1,355,296

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Heat short of fusion; volatile materials are thus driven off in the presence of chemical changes, giving more stable material for refractory use.

[2]More or less plastic brick and materials that, after the addition of any water needed, are rammed into place.

[3]Materials for domestic use as finished refractories and all exported material.

[4]Includes calcined clay, ground brick, and siliceous and other gunning mixes.

[5]Molten cast refractories are made by fusing refractory oxides and pouring the molten material into molds to form finished shapes.

[6]Completely melted and cooled, then crushed and graded for use in a refractory.

[7]Includes shipments to refractory producers for reprocessing in the manufacture of other refractories.

Source: Bureau of the Census Report Form MQ32C(87), Current Industrial Reports—Refractory.

Table 25.—U.S. exports of clays in 1987, by country

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	(2)	63	--	--	(2)	2	16	3,717	(2)	190	17	3,972
Australia	(2)	4	--	--	21	1,385	--	--	16	4,901	3	3,840	40	10,130
Belgium-Luxembourg	--	--	5	264	25	1,753	(2)	9	54	8,440	2	2,338	86	12,804
Brazil	(2)	10	8	1,767	(2)	6	(2)	42	3	1,352	13	15,034	25	18,211
Canada	26	1,043	244	9,985	24	1,874	82	5,862	413	104,140	80	13,271	869	136,175
Chile	1	29	4	459	(2)	4	--	--	6	1,739	1	554	12	2,785
Colombia	--	--	(2)	235	(2)	18	--	--	8	1,772	6	4,109	15	6,134
Ecuador	1	91	1	104	(2)	13	--	--	5	474	1	562	8	1,244
Finland	--	--	--	--	--	--	--	--	95	11,646	1	1,002	96	12,648
France	--	--	4	272	1	183	(2)	45	13	2,784	1	843	19	4,127
Germany, Federal Republic of	(2)	6	3	196	(2)	33	(2)	42	24	4,151	11	5,127	39	9,555
Hong Kong	(2)	4	1	238	--	--	--	--	1	149	(2)	54	3	445
Italy	1	12	4	330	5	433	(2)	85	201	22,131	1	241	212	23,232
Japan	1	204	114	9,904	38	2,970	1	227	561	83,958	57	12,709	772	109,972
Korea, Republic of	(2)	36	3	1,737	1	41	(2)	7	84	15,584	2	350	91	17,755
Mexico	143	4,194	7	418	19	882	(2)	61	96	10,074	59	13,401	324	29,030
Netherlands	(2)	3	4	624	(2)	49	18	1,152	192	17,697	18	7,873	233	27,398
Peru	(2)	13	1	103	--	--	--	--	2	456	1	491	4	1,063
Philippines	3	254	4	899	--	--	(2)	7	4	1,188	1	265	12	2,613
Saudi Arabia	--	--	--	--	--	--	(2)	56	(2)	22	1	473	2	551
Singapore	--	--	15	1,332	--	--	(2)	13	1	213	1	469	17	2,027
South Africa, Republic of	(2)	4	14	744	(2)	2	1	176	20	4,013	1	407	37	5,346
Spain	--	--	(2)	141	--	--	--	--	16	2,511	(2)	160	17	2,812
Sweden	(2)	3	(2)	16	3	278	(2)	23	49	8,190	9	1,277	62	9,787
Switzerland	--	--	(2)	8	17	1,346	--	--	1	227	(2)	41	19	1,622
Taiwan	(2)	6	20	2,276	2	162	--	--	64	11,503	2	420	8	14,367
Thailand	(2)	4	3	443	--	--	--	--	7	1,856	1	140	11	2,443
United Kingdom	(2)	16	9	1,411	15	946	1	171	10	1,994	16	10,843	51	15,381
Venezuela	(2)	112	19	1,913	(2)	228	1	422	23	4,862	4	1,885	48	9,362
Other	2	225	50	4,715	1	55	(2)	265	40	8,792	10	5,921	103	19,973
Total[1]	179	6,274	539	40,596	174	12,661	107	8,670	2,026	340,475	301	104,292	3,332	512,964

[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.

Source: U.S. Department of Commerce.

Table 26.—U.S. imports for consumption of clays in 1987, by kind

Kind	Quantity (short tons)	Value (thousands)
China clay or kaolin:		
Canada	20	$3
China	3	1
Germany, Federal Republic of	226	56
Netherlands	52	14
United Kingdom	10,223	1,321
Total[1]	10,524	1,397
Fuller's earth, not beneficiated:		
France	119	15
India	48	6
Total[1]	167	22
Fuller's earth, beneficiated:		
Canada	34	6
United Kingdom	63	12
Total	97	18
Bentonite:		
Brazil	1	4
Canada	1,677	420
France	10	1
Germany, Federal Republic of	454	285
Hong Kong	20	3
India	24	3
Japan	249	13
Mexico	1,341	54
Philippines	76	10
Switzerland	65	111
United Kingdom	122	39
Total[1]	4,039	945
Common blue and other ball clay, not beneficiated:		
Canada	44	8
United Kingdom	513	39
Total	557	47
Canada	2	4
Japan	231	34
United Kingdom	969	154
Total	1,202	192
Other clay, not beneficiated:		
Canada	272	16
Germany, Federal Republic of	2,500	20
Italy	196	34
Korea, Republic of	118	21
Mexico	50	15
Netherlands	265	24
Switzerland	9	7
Taiwan	2	2
United Kingdom	737	104
Total[1]	4,149	242
Clay, n.e.c., beneficiated:		
Brazil	27	22
Canada	198	97
Denmark	15	3
France	128	74
Germany, Federal Republic of	66	63
Italy	22	42
Japan	38	85
Morocco	7	2
Netherlands	44	44
United Kingdom	1,828	665
Total[1]	2,373	1,098
Artificially activated clay:		
Belgium	20	33
Brazil	6	8
Canada	23	7
Chile	1	3
France	8	10
Germany, Federal Republic of	1,102	2,471

See footnote at end of table.

Table 26.—U.S. imports for consumption of clays in 1987, by kind —Continued

Kind	Quantity (short tons)	Value (thousands)
Artificially activated clay —Continued		
Korea, Republic of	78	$14
Mexico	12,686	2,767
South Africa, Republic of	560	1,006
Sweden	2	4
United Kingdom	85	108
Total[1]	14,571	5,431
Grand total[1]	37,679	9,392

[1]Data may not add to totals shown because of independent rounding.

Source: U.S. Department of Commerce.

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Australia.—Comalco Kaolin's kaolin clay mining and processing operation at its Weipa bauxite mine in northern Queensland, with an initial capacity of 100,000 tpy, was officially inaugurated.[2] Indicated reserves, just below the bauxite layer, totaled 25 million tons, but further exploration suggests that the total reserves could easily be twice this tonnage.

Comalco aims to be a major supplier to the paper coating industries of Western Europe, Japan, and the entire Pacific Basin. Exports, valued at $16 million, were expected to rapidly consume the plant's initial capacity.

In another kaolin event, ECC-Pacific completed an expansion at its Pittong plant with further expansion to be completed by 1988, bringing capacity up to 75,000 tpy.[3] Further increases were planned within the next 2 years to eventually raise production up to 120,000 tpy. Increases in capacity at Pittong have been matched by improvements in the wet- and dry-distribution facilities at the port of Fowey. With these strategically aimed expansions, ECC International planned not only to hold on to its present position in the world marketplace, but also to increase its market share internationally.

Belgium.—The Belgian chemical group, Solvay & Cie. S.A., purchased a further 1.17 million common shares in Laporte Industries (Holdings) PLC, raising its total share in the company to 22%.[4] (See "United Kingdom" and "Fuller's Earth" sections of this chapter.)

Brazil.—The Azevedo Antunes Group continued investing in its kaolin mines in the northern part of Amapá Territory.[5] The expansion program, scheduled for completion by yearend, was to nearly double production to 400,000 tpy. In another kaolin action, ECC's existing operation at Maji das Cruzes was extended to greater than 100,000-tpy capacity after a series of newly completed expansions.[6] ECC was the largest supplier of pigments to the Brazilian paper industry.

Canada.—A drilling and coring program was successfully concluded at the Wood Mountain kaolin project in Saskatchewan by Ekaton Industries Inc.[7] The drilling program was designed for both reserve evaluations and pilot plant testing. Earlier testing revealed a 200-million-ton ore body with a low 80's GE brightness, good optical characteristics, and a marketable calcined variety. The calcined clay is being targeted for eastern Canada, the Pacific Basin, and European markets. The pilot plant cost $1.5 million, and the entire project was estimated at $25 million for a 150,000-tpy facility. In midyear, Ekaton also signed a letter of intent with Esso Minerals Canada Ltd. whereby Esso acquired an option to accumulate up to 65% of the property due for completion by yearend 1988. In another action, Ekaton started construction of a $3 million absorbent plant in Kamploops, British Columbia.[8] Ekaton will become the only Canadian producer of clay-base pet waste and industrial absorbents. The project was approved only after an extensive market study showed that market share for clay-base absorbents had increased dramatically in western Canada.

In a common clay action, Brampton Brick Ltd. signed a contract with Agemac Ltd. to build a 120-million-bpy turnkey plant in Brampton, Ontario, by the spring of 1988.[9] The fully automated plant, requiring only

eight people for overall operation, will feature a primary grinding installation, two tunnel dryers each with a 32-kiln-car capacity, and two 415-foot top- and side-fired tunnel kilns with a firing capacity of 178,000 bpy. Another common clay event saw Canada Brick Co. select Frame Engineering Inc., Anniston, AL, to provide a turnkey facility for the first dry fluoride scrubber system in a North American brick plant.[10]

Chile.—A newly completed feasibility and requirements study, in terms of investment, by Corporación de Fomento de la Producción's Servicio de Cooperación Téchnica (SERCOTEC) revealed the viability of several new medium- and small-scale mineral-related businesses.[11] One venture of interest was a brick manufacturing requirement for the midsouthern market area of the country. The brick facility would have an annual capacity of 3.2 million bricks requiring an initial investment of less than $1 million.

Finland.—The Government's Geological Research Institute was mounting a major exploration program designed to make the country self-sufficient in kaolin clays. The Finnish paper industry's demand for kaolin paper grade clays was estimated to be 1.5 million tons by 1990. In other kaolin developments, Kemira Oy was examining a promising deposit at Virtasalmi. Kemira planned to build a 100,000-tpy plant if the deposit contains more than 10 million tons of reserves. Partek Oy signed a cooperative agreement with a Swedish research organization to prepare a feasibility study on developing the Swedish Rostanga kaolin deposit.[12]

Germany, Federal Republic of.—Watts Blake Bearne Co. plc, United Kingdom, purchased a West German prepared-ceramic-body producer, Kannenbaeckerland, for about $6 million through its wholly owned subsidiary, Fuchs'she Tongruben (FT). FT, a major clay and prepared-ceramic-body producer, is one of the largest suppliers to the European stoneware and earthenware industry.[13] The European Darex Div. of W. R. Grace & Co. began construction to double capacity of its FCC plant in Worms.[14] The $20 million expansion, scheduled for completion by midyear 1989, was in response to increasing demand for these kaolin-derived FCC in Europe and the Middle East. W. R. Grace mines kaolin in the United States and manufactures its catalyst line in Aiken, SC, Cincinnati, OH; and Chattanooga, TN.

Indonesia.—The Government's Mining and Mineral Research Center predicted that by 1990 Indonesia will become one of the world's preeminent kaolin producers. The Center further stated that in 1987 there were 27 kaolin producers (all domestic companies because of Government regulations) in Indonesia. There were 7 mines on Bangka Island, 17 on Belitung, 2 in West Java, and 1 in North Sulawesi. P.T. Tambang Timah, a major producer, completed a new kaolin mining and processing complex at Tanjung Pandan on Belitung Island, South Sumatra, with an installed capacity of 22,000 tpy. The new plant's total production was to be equally divided between domestic and overseas Japanese consumers. Domestic kaolin production was consumed mostly by ceramic roof tile, cosmetic, paint, paper, and rubber manufacturers.[15]

Malaysia.—A kaolin deposit at Telagus, western Sarawak, was being evaluated by the recently formed Sarawak China Clay Trust.[16] The deposit lies 65 miles southwest of the proposed shipping terminal at Kuching on the South China Sea. Preliminary studies indicated a reserve of approximately 20 million tons and low viscosity characteristics combined with a brightness in the 70% to 86% range. A wet-processing facility with a capacity of 150,000 tpy is planned, with consideration given to an additional 150,000 tons at some later date.

Netherlands.—Redland PLC, under its right of first refusal, acquired the other half of its Dutch subsidiary, Redland-Brass-Bredero Europa BV, from Venenigde Bedrijven Bredero (VBB).[17] VBB is a major Dutch producer of bricks, ceramic tiles, concrete roofing tiles, and other building products.

Pakistan.—Residual buried kaolin deposits, formed as alteration products from granitic feldspars, are found near Nagar Parker in the Thar Parker District of southeast Sind, about 400 miles from Karachi. The Pakistan Mineral Development Corp. Ltd. (PMDC) identified more than 35 of these kaolin pockets overlain either by alluvium and/or laterite beds. Proven reserves were estimated at more than 4 million tons. PMDC plans to install a 50,000-tpy capacity raw kaolin elutriation plant for producing paper-, filler-, and ceramic-grade clays. Thar Mineral Processing Enterprise Ltd., in the same area, and Sind Minerals Ltd. in Mirpurkhas were reportedly also interested in establishing washing plants in the Nagar

Parker. In a fuller's earth development, the Punjab Mineral Development Corp. (Punjmin) started mining a montmorillonite clay at Dalona for use as an acid-activated bleaching earth. Presently, activated clays are largely imported for processing ghee and other edible oils. Expansions were also planned to eventually replace imported bleaching earths.[18]

Spain.—English China Clays PLC, through its subsidiary ECC Overseas Investments Ltd., increased its involvement in Spanish kaolin by acquiring 75% of the stock in Caosil S.A. for an undisclosed sum.[19]

ECC also had a 81.6% controlling interest in Cía. Española de Caolines S.A. (Cedecsa). The Caosil and Cedecsa kaolinitic sand deposits will be operated separately. Caosil's quarries were at Peñalen in Guadalajara and wet-processed at Villaneuva. Kaolin from this complex, roughly 30,000 tpy, was mainly for the ceramics and paper industries. Cedecsa produced paper-grade kaolins, both coater and filler, from an operation at Poveda de la Sierra, also in Guadalajara. Coproduct bottle glass and ceramic grit sands were also produced at these locations.

U.S.S.R.—A large fully automated ceramic wall tile factory capable of producing about 75 million tiles per year was to be constructed in Novosibirsk.[20]

United Kingdom.—In view of a steady increase in demand worldwide for white pigments for the paper industry, ECC International Ltd. reported a number of developments to enable more marketplace efficiencies. In Cornwall and Devon, a major drive was authorized to boost production from the company's existing plants. Additional flotation and new comminution equipment had been added to permit both recovery of the valuable large particle-size kaolin and to increase output from the flotation units. Two new pits also were scheduled to come on-stream along with the newly recommissioned Lower Longstones clayworks, idle since the mid-1970's. A new greenfield site also was said to be near development in the St. Austell clay-bearing area and was expected to be completed by yearend 1988. In addition to seeking extra sources of clay and improved recovery, ECC was also contemplating further expansions at its Par Clay Slurry plant and Blackpool works. Improved filtration systems at the clay-drying plants were added to increase efficiency and throughput and reduce overhead. In total, the package of improvements reportedly represented an increase of more than 20% in production.[21]

The major increased production in Cornwall and Devon, largely targeted for export, required the upgrading of ECC's marshalling and discharge facilities in the port of Fowey.[22] Railfreight, in addition, also announced plans to build specialized hopper cars to transport china clay from ECC's clayworks to the port and to modernize British Rail's depot at St. Blazey. The Goonwean and Rostowrack China Clay Co. Ltd., the long- established independent producer with three Cornish pits, installed a new powder blend plant in St. Austell, Cornwall.[23] The new materials handling equipment included storage and handling systems with both mechanical and pneumatic conveyors.

Steetley Berk Ltd., a subsidiary of Steetley PLC, commissioned a new fully automated absorbent products mineral packing and distribution plant at Flixborough near Scunthorpe in South Humberside. The plant, to be opened at midyear, was to provide a full line of pet waste and industrial absorbent products. In addition, the plant was also designed with the ability to pack Spanish sepiolite clays from the producing Provinces of Madrid and Toledo. The Flixborough location was chosen solely because of its proximity to nearby Trent ports and important domestic freight routes for market distribution.[24] The international chemicals group of Laporte Industries disclosed plans to begin recovering fuller's earth from new deposits in Surrey, pending results of a scheduled public inquiry.[25] Hepworth Ceramic Holdings PLC bid for Thomas Marshall (Loxley) PLC, a fire clay refractory manufacturer.[26] Hepworth had three main areas of interest: the manufacture of clay pipes and plastic products for the building industry, the processing of silica sands mainly for the glass and foundry industries, and the manufacture of clay and basic refractory products. The Marshall acquisition will enable Hepworth to merge its other refractory subsidiary, G. R. Stein, and to exploit Marshall's presence in North America and Stein's extensive export base.

Table 27.—Kaolin: World production, by country[1]

(Thousand short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria	e19	9	14	16	15
Argentina	160	100	81	129	110
Australia[3]	127	e241	e188	e140	165
Austria (marketable)	92	110	110	51	50
Bangladesh[3]	3	3	5	3	e14
Belgium	66	76	41	e44	e42
Brazil (beneficiated)	463	536	578	588	710
Bulgaria	267	282	283	292	290
Burundi	4	2	5	6	6
Chile	45	54	54	46	e48
Colombia	1,114	1,034	1,148	1,714	e1,346
Costa Rica[e]	1	1	--	--	--
Czechoslovakia	730	736	e720	e720	e768
Denmark[e]	11	15	14	e11	12
Ecuador	1	r3	3	e2	2
Egypt	110	159	119	141	145
Ethiopia (including Eritrea)[e]	10	10	10	10	6
France[7]	319	338	1,664	1,488	1,540
German Democratic Republic (marketable)[e]	220	190	190	180	165
Germany, Federal Republic of (marketable)	448	397	452	564	550
Greece	67	101	97	156	160
Hong Kong	1	(8)	11	1	--
Hungary	41	43	32	33	e37
India:					
Salable, crude	610	555	645	808	e870
Processed	e110	128	121	e110	165
Indonesia	66	92	118	138	140
Iran[e]	110	110	110	110	110
Israel[e]	e30	30	30	30	30
Italy:					
Crude	58	58	66	39	e134
Kaolinitic earth	28	28	29	21	e26
Japan	254	248	245	225	e175
Kenya	1	(8)	(8)	2	2
Korea, Republic of	754	795	726	937	e695
Madagascar[e]	3	3	e7	e7	e2
Malaysia	63	80	91	94	104
Mexico	179	144	311	e220	220
Mozambique	(8)	(8)	(8)	e(8)	(8)
New Zealand	26	28	e30	e30	30
Nigeria[e]	1	(e 8)	(8)	(8)	(8)
Pakistan	14	13	7	41	35
Paraguay	50	55	66	e66	66
Peru	1	1	(8)	7	6
Poland	54	50	53	54	54
Portugal	114	115	88	60	e63
Romania[e]	450	450	450	r450	440
South Africa, Republic of	143	150	142	139	e167
Spain (marketable)[9]	281	352	456	413	420
Sri Lanka	9	12	6	7	e8
Sweden	(8)	(8)	e(8)	e(8)	(8)
Taiwan	113	88	84	70	e74
Tanzania	1	2	2	e2	2
Thailand	40	65	118	r146	e r228
Turkey	e60	61	76	86	e148
U.S.S.R.[e]	2,900	3,100	3,200	3,300	3,300
United Kingdom	3,000	3,286	3,472	e3,400	3,500
United States[10]	7,203	7,953	7,793	8,549	e8,827
Venezuela	12	24	e25	24	32
Vietnam[e]	1	1	1	1	1
Yugoslavia	230	222	r e225	r e230	235
Zimbabwe	1	1	1	1	1
Total	21,289	r22,750	24,608	26,152	26,491

eEstimated. pPreliminary. rRevised.

[1]Table includes data available through July 15, 1988.

[2]In addition to the countries listed, China, Lebanon, and Suriname also produced kaolin, but information is inadequate to make reliable estimates of output levels. Guatemala and Morocco each produced less than 500 tons in each of the years covered by this table.

[3]May include ball clay and other clays grouped for statistical purposes as kaolin.

[4]Excludes Western Australia.

[5]Data are for year ending June 30 of that stated.

[6]Reported figure.

[7]Includes kaolinitic clay.

[8]Less than 1/2 unit.

[9]Includes crude and washed kaolin and refractory clays not further described.

[10]Kaolin sold or used by producers.

Table 28.—Bentonite: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[3]	e38,100	r27,007	36,376	33,069	33,000
Argentina	149,439	r138,564	162,111	161,148	159,800
Australia[3]	33,098	43,180	32,044	27,494	27,500
Brazil	141,857	221,592	280,168	227,099	231,500
Burma	783	799	783	908	900
Cyprus[4]	r35,274	35,715	57,320	60,627	62,800
Egypt[e]	2,800	4,200	3,300	r5,650	5,700
France	3,407	3,831	16,424	e11,000	9,000
Greece	759,427	858,400	977,718	1,452,652	1,322,800
Guatemala[e]	8,800	9,400	e3,006	r2,800	2,900
Hungary	87,972	70,722	65,986	88,061	5108,391
Iran	15,432	38,581	29,762	r e30,000	30,000
Israel (metabentonite)	7,588	6,501	e6,600	e6,600	6,600
Italy	327,183	335,102	327,239	336,890	5364,149
Japan	486,034	452,034	508,749	527,184	5458,347
Kenya[e]	220	220	220	220	220
Mexico	249,276	294,700	295,083	160,937	165,300
Morocco	4,515	2,012	8,171	4,226	53,250
Mozambique	276	446	398	1,226	1,200
New Zealand (processed)	2,158	7,075	e6,600	e6,600	6,600
Pakistan	735	1,918	1,776	1,501	2,600
Peru	16,656	14,296	2,223	36,464	33,100
Philippines	739	42,162	27,526	e22,000	22,000
Poland[e]	77,000	77,000	83,000	83,000	83,000
Romania[e]	195,000	198,000	198,000	204,000	198,000
South Africa, Republic of	43,573	46,131	47,910	53,203	553,961
Spain	90,976	80,008	90,471	e88,000	89,000
Tanzania[e]	83	83	83	83	83
Turkey	e34,200	30,967	51,649	61,032	594,631
U.S.S.R.[e]	3,163,600	3,174,700	3,185,700	3,196,700	3,196,700
United States	2,886,870	3,437,940	3,195,280	2,813,043	52,806,233
Zimbabwe	69,552	e77,000	--	--	--
Total	r8,927,573	r9,730,288	9,685,656	9,708,447	9,579,265

eEstimated. pPreliminary. rRevised.

[1]Table includes data available through July 22, 1988.

[2]In addition to the countries listed, Canada, China, the Federal Republic of Germany, and Yugoslavia are believed to produce bentonite, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3]Includes bentonitic clays.

[4]Includes bleaching earths.

[5]Reported figure.

Table 29.—Fuller's earth: World production, by country[1]

(Short tons)

Country[2]	1983	1984	1985	1986[p]	1987[e]
Algeria[e]	5,500	53,858	3,900	3,900	3,900
Argentina	7,431	3,980	1,921	r e2,200	2,200
Australia (attapulgite)[e]	16,500	16,500	16,500	16,500	16,500
Italy	e22,000	e33,000	33,500	34,127	542,449
Mexico	45,827	50,372	63,934	e49,600	49,600
Morocco (smectite)	30,187	36,824	26,924	38,691	551,005
Pakistan	23,298	21,097	11,736	16,785	18,700
Senegal (attapulgite)	110,644	127,315	105,774	90,232	5122,409
South Africa, Republic of	344	--	--	--	--
Spain (attapulgite)	49,223	48,399	65,805	e56,000	58,400
United Kingdom	211,644	222,666	e220,000	e220,000	220,000
United States[4]	1,911,634	1,899,145	2,059,281	1,909,978	52,056,791
Total	2,434,232	2,463,156	2,609,295	2,428,013	2,641,954

eEstimated. pPreliminary. rRevised.

[1]Excludes centrally planned economy countries, some of which presumably produce fuller's earth, but for which no information is available. Table includes data available through July 22, 1988.

[2]In addition to the market economy countries listed, France, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3]Reported figure.

[4]Sold or used by producers.

A $2 million contract was awarded to a Cardiff-based engineering group by ARC Powell Duffryn Brick Ltd., Risca, Gwent, for the reported construction of Europe's most modern brick factory to meet the increased demand for the company's bricks.[37] The new 35-million-bpy plant at Cirencester, Gloucestershire, to be commissioned at midyear, was to be fully automated and to incorporate the latest computer-aided technology. The factory, ARC Powell Duffryn Brick's sixth, is to be built adjacent to the quarry on a 4-acre site. Baggeridge Brick PLC announced a $15 million enlargement at its Kingsbury brickworks.[38] Contracts were signed with several brickmaking equipment companies and included a Clay Fawcett clay preparation plant and Lingl setting equipment and tunnel kiln, jointly designed by the latter and Baggeridge. Steetley acquired Lumley Brickwork Ltd., a well-established manufacturer of face brick in the northeast.[39] Steetley was planning to invest substantially in the Lumley business as part of its expansion north of England. Steetley's present brick holdings in 1987, Steetley Brick and Tile, headquartered in Newcastle-under-Lyme already was a leading supplier of facing brick and clay roof tiles in central England. Steetley was also actively increasing production capacity through major expansions at Parkhouse (bricks), Keele, and Knutton (tile).

TECHNOLOGY

The high-temperature properties of two clay fluids, formulated from commercially available domestic sodium bentonite and bentonite-saponite mixtures, were evaluated in the temperature range 300° to 600° F under appropriate confining pressures up to 16,000 pounds per square inch.[30] The study was designed to evaluate the effects of common drilling mud additives (such as sodium polyacrylates, lignite, and lignosulfonates) and formation contaminates (such as potassium, sodium, and calcium salts) in a geothermal well environment. The addition of saponitic clays to the bentonitic fluids exhibited a balanced viscosity at all temperatures and conditions tested. A constant viscosity is mandatory for optimizing drilling systems. The catalytic properties of layered aluminosilicate smectite-type clays were reviewed.[31] These catalysts have long been used for cracking hydrocarbons. More recent applications of intercalated clay catalysts and/or supports along with new clay-related chemistry, have burgeoned in recent years. There was further information about specific uses of clays in carbocatonic reactions and condensations of clay surfaces to cycloadditions and rearrangements and to redox reactions. The role of clay in biogenesis and/or prebiotic synthesis of the first biomolecules also was explored. The selective sorption of water-soluble oligomers, ethylene glycol, and ethylenimine, were observed on synthetic sediments containing predetermined amounts of kaolinite, illite, and montmorillonite clays.[32] This type of research should aid the design of inexpensive clay-base systems that preferentially strip unwanted contaminates and/or toxins from environmentally sensitive air and water systems. The tremendous diversity of modifying reagents in the rapidly advancing surface modification of minerals area, including kaolin and complex organic coupling agents to improve a particular mineral's mechanical, decorative, and thermal properties, are detailed.[33] The article cited specific examples of surface treatment describing the coating chemistry evaluated, the mode of application, and principal market outlets. A similar work focused on surface treatment of kaolins to improve the performance of filled nylon products.[34] Listed were improvements in flexural modulus heat deflection temperature and impact strength. Surface-treated calcined kaolin reinforcement is used in engineered high-tech compounds. Silane loading levels were also identified and compared for both medium- and fine-particle kaolins. Articles reviewed the growing mineral markets in plastics and paper. One article on plastics examined selected market sectors technically, specifically resins and thermosets, and related their consumption of mineral fillers in reinforcements and pigments for interior and exterior applications.[35] Another article outlined the technical means whereby plastics producers and fabricators can improve market position and/or penetration through innovation.[36] The area of greatest potential appeared to be product modification and/or redesign. The sales of unaltered minerals and surface-modified minerals also were examined. An article on paper reviewed the world sources of kaolin and its major markets.[37] The individual companies in each country, their products, capacities,

locations, plans, and other pertinent data were highlighted. The other paper stressed the current and future technical trends in Western European graphic paper production.[39] The impact of mineral usage in graphic paper also was discussed. One section of the work presented a discussion on the industry structure, on a countrywide basis, stressing features such as mill capacities and output, paper grades, and new investment programs.

Statistical process control (SPC) in the mining and processing of air-floated kaolin was detailed.[40] SPC in this context is basically a cooperative agreement between a raw material supplier and a manufacturer that provides for quality assurance. The costly and time-consuming aspects of SPC are apparently being overridden by an ever-growing customer base of clay purchasers demanding improved and reliable product quality. Thermally activated kaolin and montmorillonites in a fixed-bed reactor were shown to have excellent pozzolanic activity when mixed with lime and water.[42] The material, readily available as an inexpensive raw clay, apparently possesses sufficient strength to permit use as a low-cost binder in developing countries. It is of interest to evaluate swelling-type clays for use as a pozzolana because they are conventionally excluded from consideration for building construction.

A comprehensive treatise looked at kaolin and associated clay minerals, such as ball, fire, and flint clays, from a geological viewpoint and described the classifications, origins, and mineralogy of worldwide kaolin deposits.[41] The paper, highlighting the deposits in the United States and the United Kingdom, also reviewed the main sources of kaolin and its major markets. A noteworthy aspect of the report was the exhaustive tables of typical kaolin filler, coating, and ceramic grade clays containing both physical and chemical properties. Similar tables are also shown for ball clays, flint clays, fire clays, and chamotte. An article focusing on the clay mineral potential of Turkey was published.[43] The article looks at the geology and formation of the Turkish clay deposits followed by the classification and outlook of the clay minerals encountered. Reserves, production, quality, and markets for kaolin, ball clays, refractory clays, bentonite (both white and sodium bentonite), sepiolites, and saponites are given in detail. A concise study on the industrial minerals of Pakistan included sections on kaolin, fuller's earth, bentonite, and fire clays in the four Provinces.[43] Geology, mining, production flowsheets, and operating companies were presented. A number of clay-testing techniques that must be applied in the proper technical evaluation of clays for use in ceramics was summarized.[44] The author exhorted those in the extractive industry to employ testwork programs specifically designed to assess the manufacturing potential of the clay raw materials to eliminate the ubiquitious downstream problems.

A series of papers described the technical aspects of mullite in the binary system Al_2O_3-SiO_2. One paper investigated the alumina-silica phase relations of samples annealed in oxygen, quenched, and studied by optical microscopy, image analysis, X-ray diffraction, and by the transmission electron microscope (TEM).[45] Careful analyses of data revealed that the solid solution boundaries of mullite changed with increasing temperature up to its peritectic melting at 1,890° C. A similar investigative technique, including differential thermal analysis (DTA), showed that the spinel phase form during the 980° C exothermic reaction in the kaolinite-mullite reaction series was nearly a pure Al_2O_3 composition.[46] Detailed TEM characterization indicated that the spinel formation is preceded by a phase separation in the amorphous dehydroxylated kaolinite matrix. The remaining two papers characterized mullites formed by sol-gel methods classified as either colloidal or polymeric.[47] The specimens formed from mullitic compositions from colloidal powders had mullite grains of prismatic shape and a liquid phase. With polymeric powders, mullite grains were equigranular with no liquid phase. The colloidal mullites were considered to be metastable, resulting from the nature of the starting material and processing conditions employed. The other research showed that mullite derived from slow-hydrolysis methods from silanes and hydrous aluminum nitrates gradually approached the stoichiometry of the bulk composition as the firing temperature increased and slightly departed again on further heating.[48] The mullites, which are end products of solid-state reactions involving kaolin, are widely used in refractory bricks and specialty products. The results of this basic research should allow refractory manufacturers to better control the physical properties of the mullite component to optimize the density of the resulting high-performance refractories.

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